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GAS EBULLITION EVALUATION

REMEDIAL INVESTIGATION/FEASIBILITY STUDY, NEWTOWN CREEK

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LIST OF ACRONYMS AND ABBREVIATIONS

14C	carbon-14
AIS	Automatic Identification System
AOC	Administrative Order on Consent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	centimeter
CM	creek mile
CSO	combined sewer overflow
CSTAG	Contaminated Sediments Technical Advisory Group
FES	field gas ebullition survey
FS	Feasibility Study
FS DSR Part 1	*Feasibility Study Field Program Data Summary Report Part 1*
FS FP Work Plan and FSAP – Addendum No. 2	*Feasibility Study Field Program Work Plan and Field Sampling and Analysis Plan Addendum No. 2: Gas Ebullition Field Program*
FS Gas Ebullition DER	*Feasibility Study Gas Ebullition Data Evaluation Report*
L/m²/day	liters per square meter per day
mg	milligram
mg/m²/day	milligrams per square meter per day
MLLW	mean lower low water
NAPL	nonaqueous phase liquid
NOAA	National Oceanic and Atmospheric Administration
OPA	oil-particle aggregate
ORP	oxidation reduction potential
PAH	polycyclic aromatic hydrocarbon
Phase 2 DSR	*Phase 2 Remedial Investigation Field Program Data Summary Report*
Phase 2 FSAP Volume 2 Addendum No. 3	*Phase 2 Field Sampling and Analysis Plan – Volume 2 Addendum No. 3*
Phase 2 FSAP Volume 2 Addendum No. 4	*Phase 2 Field Sampling and Analysis Plan – Volume 2 Addendum No. 4*

RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RI Report	*Remedial Investigation Report*
TEAP	terminal electron acceptor product
TOC	total organic carbon
TPAH (17)	total polycyclic aromatic hydrocarbon (17)
TPH	total petroleum hydrocarbon
USEPA	U.S. Environmental Protection Agency
WSE	water surface elevation

1 INTRODUCTION

1.1 Background

The Newtown Creek Remedial Investigation (RI) sampling program was conducted in two phases, performed under U.S. Environmental Protection Agency (USEPA) oversight, following methods and procedures described in USEPA-approved work plans. Gas ebullition investigation programs were performed for the RI, and additional programs were performed for the Feasibility Study (FS) as follows:

- As part of the Phase 2 RI field program, qualitative field gas ebullition surveys (FESs) were conducted in August 2015 and September 2016 in the Study Area[1] to characterize the presence and extent of gas ebullition-facilitated nonaqueous phase liquid (NAPL)/contaminant transport in the Study Area through the following:
  - Observing the surface water for visual evidence of gas ebullition and documenting observations
  - Developing a preliminary understanding of the site conditions where gas ebullition is most likely to occur
  - Observing the surface water for the presence of static sheens and sheen blossoms, visually characterizing sheens, and identifying potential sheen sources
  - Visually characterizing sheens associated with gas ebullition, or otherwise observed in the survey areas

[1] The Newtown Creek Superfund Site Study Area is described in the Administrative Order on Consent (AOC) as encompassing the body of water known as Newtown Creek, situated at the border of the boroughs of Brooklyn (Kings County) and Queens (Queens County) in the City of New York and the State of New York, roughly centered at the geographic coordinates of 40° 42' 54.69" north latitude (40.715192°) and 73° 55' 50.74" west longitude (-73.930762°), having an approximate 3.8-mile reach, including Newtown Creek proper and its five branches (or tributaries) known respectively as Dutch Kills, Maspeth Creek, Whale Creek, East Branch, and English Kills, as well as the sediments below the water and the water column above the sediments, up to and including the landward edge of the shoreline, and including also any bulkheads or riprap containing the waterbody, except where no bulkhead or riprap exists, then the Study Area shall extend to the ordinary high water mark, as defined in 33 Code of Federal Regulations (CFR) §328(e) and the areal extent of the contamination from such area, but not including upland areas beyond the landward edge of the shoreline (notwithstanding that such upland areas may subsequently be identified as sources of contamination to the waterbody and its sediments or that such upland areas may be included within the scope of the Newtown Creek Superfund Site as listed pursuant to Section 105(a)(8) of Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]).

- In Part 1 of the FS field activities, a quantitative gas ebullition pilot study was conducted in September 2017 to develop and test methodologies for the FS gas ebullition field program planned for Part 2 of the FS field program.
- In Part 2 of the FS field program, gas ebullition investigations in 2018 and 2019 were conducted to quantify NAPL/contaminant flux associated with gas ebullition.

The RI gas ebullition observation surveys, FS Part 1 field gas ebullition pilot study activities, discussion of the results, and an evaluation of the processes that generate and influence gas ebullition and NAPL/contaminant transport are provided in this document. The results of the FS Part 2-related gas ebullition field programs conducted in 2018 and 2019 are provided in a subsequent FS-related report (*Feasibility Study Gas Ebullition Data Evaluation Report* [FS Gas Ebullition DER; Anchor QEA 2021]).

Gas ebullition is the formation and migration of gas bubbles (Viana et al. 2007; McLinn and Stolzenburg 2009). Methanogenesis is the primary gas producing process in aquatic sediment gas ebullition, producing mostly methane in organic-enriched sediments (Fendinger et al. 1992; Poissant et al. 2007; Viana et al. 2007). Methanogenesis results from anaerobic decomposition of organic material in the sediment and generates mostly methane with lesser amounts of carbon dioxide and other gases (Viana et al. 2007). Gas ebullition includes gas bubble formation and growth as a result of this gas generation process and the subsequent upward migration of the gas bubbles through soft sediment to the surface water column. Migration of gas bubbles through NAPL or other organic contaminants in the sediments may result in the transport of NAPL/contaminants from sediments to the surface water (i.e., gas ebullition-facilitated transport). The term "NAPL/contaminants" includes NAPLs (primarily semivolatile and volatile organic compounds), contaminants associated with NAPL, and other organic contaminants. Section 2 provides further description of the gas ebullition and gas ebullition-facilitated NAPL/contaminant transport process. It is important to note that not all gas bubbles observed in the Study Area are caused by gas ebullition processes. Other gas bubble sources have been observed in the Study Area, including (but not limited to) the aeration system operated by the New York City Department of Environmental Protection in English Kills, the Turning Basin, and East Branch; outfall discharges; vessel traffic; and biota (e.g., fish and crabs).

During Phase 1 of the RI, the presence of NAPL in sediment was identified at several locations in the Study Area. Phase 2 RI sampling was conducted to delineate the NAPL and support multiple RI programs and objectives, including characterizing the presence, nature, and extent of NAPL in the Study Area sediments (see Appendix C of the *Remedial Investigation Report* [RI Report] for the NAPL Evaluation). Based on the preliminary findings during the NAPL Evaluation and the recommendation from the USEPA Contaminated Sediments Technical Advisory Group (CSTAG) that gas ebullition be evaluated as a potential transport mechanism for NAPL and other hydrophobic contaminants (CSTAG 2015), USEPA requested that the Newtown Creek Group investigate gas ebullition as a potential NAPL/contaminant transport.

FESs were performed during Phase 2 of the RI in August 2015 and September 2016; these included field data collection to characterize the occurrence and extent of gas ebullition-facilitated NAPL/contaminant transport. In particular, the September 2016 survey was conducted over 4 days during a low spring tide (lower tidal elevations) and peak seasonal water temperatures. Following these two FESs, further studies to more quantitatively measure gas ebullition-facilitated NAPL/contaminant transport were conducted (Schmidt 2016). During the FS Part 1 field activities in 2017, a pilot study was conducted to collect initial flux data and test multiple sampling methods to identify a preferred method for quantifying fluxes of NAPL/contaminants and gas for the FS gas ebullition field investigation.

The results of the Phase 2 RI FESs (August 2015 and September 2016) and FS Part 1 pilot study (2017) are presented in this appendix. Based on these results, a quantitative gas ebullition program was initiated in FS Part 2 field activities in 2018 and continued in 2019. The results of this quantitative gas ebullition program will be presented in a subsequent FS-related report.

1.2 Objectives

The overall objectives of the Gas Ebullition Evaluation study, in addition to those stated in Section 1.1, are to characterize the occurrence and extent of gas ebullition-facilitated NAPL/contaminant transport in the Study Area. This includes an evaluation of the environmental conditions that influence gas ebullition-facilitated NAPL/contaminant transport, including surface water and sediment temperature, water depth and tidal elevations, sediment strength,[2] the presence and distribution of organic content in surface (0 to 15 centimeters [cm] below mudline) and subsurface sediment, and NAPL/contaminant distribution. The results of this study will be taken into consideration during the FS process and as part of the remedial design process.

1.3 Appendix D Organization

This appendix includes the following items:

- An overview of the gas ebullition and gas ebullition-facilitated NAPL/contaminant transport processes, including the environmental conditions that impact the processes (Section 2)
- A discussion of the 2015 and 2016 FESs and 2017 pilot study, including the types of data collected, field methods, and location and timing of the studies (Section 3)
- The results of the 2015 through 2017 field programs, including spatial extent and frequency of visual observations, NAPL/contaminant and gas flux measurements from the pilot study, and environmental conditions measured during each of the studies (Section 4)
- A synthesis of the gas ebullition evaluation, including potential sources for methanogenesis, and the influence of water depth, periodic changes in tidal elevation, seasonal surface water temperatures, and the interaction between gas ebullition and sediment NAPL/contaminants on the gas ebullition process (Section 5)
- Summary and conclusions (Section 6)
- References (Section 7)

[2] "Sediment strength" refers to a material characteristic of the sediment to resist fracture and formation of bubble migration pathways, due to stresses induced on the sediment by gas bubble formation and growth.

2 GAS EBULLITION AND NAPL/CONTAMINANT TRANSPORT

Gas ebullition is the formation and migration of gas bubbles through soft sediment to the surface water column (Lay et al. 1996; Joyce and Jewell 2003; Algar et al. 2011). When gas ebullition and bubble migration occur through NAPL/contaminants contained in the sediment column, they have the potential to transport NAPL/contaminants to the water column. The approach and methods used during the gas ebullition field investigations were developed based on an understanding of the processes described in this section, including the environmental conditions that influence gas ebullition and gas ebullition-facilitated NAPL/contaminant transport. The additional FS data collection noted in Section 1.1, including laboratory analysis of gas, will be used to confirm the gas ebullition processes described in this section as described in the FS Gas Ebullition DER (Anchor QEA 2021).

It is important to note that methanogenesis (the primary gas producing process in aquatic sediments); gas bubble nucleation and growth (i.e., gas bubble generation); and gas bubble migration are all necessary components of gas ebullition. As described in Sections 2.1 and 2.2, methanogenesis may occur in sediment without gas ebullition necessarily occurring (e.g., in depth intervals of sediment where hydrostatic pressure and/or sediment strength suppress gas bubble generation and/or migration).

2.1 Gas Bubble Generation

Gas bubbles, which in most aquatic environments consist primarily of methane (Fendinger et al. 1992; Poissant et al. 2007; Viana et al. 2007), form in sediment as a result of the anaerobic microbial decay of labile organic matter. The labile organic material in sediment, which can act as a food and nutrient source for microorganisms associated with gas ebullition, may originate from naturally occurring aquatic vegetation and organisms, discharges of organic-rich materials (including fecal material and other anthropogenic organic material from point source discharges including combined sewer overflows [CSOs]), and other organic contaminants. Some sediments with higher total organic carbon (TOC) can also have a higher potential for gas generation (Viana et al. 2012), although this correlation may be dependent on the labile organic carbon also scaling with the TOC. A comparison of the TOC distribution throughout the Study Area and footprint of gas bubble generation is discussed in Section 5.1.1. Additional detail regarding Study Area TOC is provided in Sections 4.2.2 and 4.3.2 of the RI Report.

Microbial respiration (aerobic to anaerobic) evolves generally in the following order as available terminal electron acceptor products (TEAPs) become depleted:

- Oxygen
- Nitrate
- Manganese
- Iron
- Sulfate

In this process, bacteria utilize these TEAPs along with some organic compounds (e.g., labile organic matter and labile organic contaminants, such as fecal matter discharged through CSOs) while respiring. Initially, aerobic respiration will occur until the oxygen available in the system has been depleted. After the depletion of oxygen, respiration occurs anaerobically through the use of TEAPs other than oxygen (i.e., nitrate, manganese, iron, and sulfate). As shown in Figure D2-1, the methanogenic microbial decay of organic matter occurs only after these more energetically favorable aerobic and anaerobic respiration TEAPs, such as nitrate and sulfate, have been depleted.

Multiple processes, including methanogenesis, sulfate reduction, and denitrification, contribute to the generation of gas in sediments. Sulfate reduction and denitrification typically produce relatively small quantities of gases due to limitations of the TEAPs, whereas methanogenesis typically produces relatively large quantities of gas (primarily methane) when the supply of labile organic matter is not limited. Therefore, methanogenesis is typically the primary source of gases in sediment (Poissant et al. 2007).

The rate of microbial activity and gas generation is directly affected by sediment temperature, which changes throughout the year and can be additionally impacted by water and sediment depth (Viana et al. 2012). Sediment temperature affects methanogenesis (as well as all microbial degradation processes), because relatively high temperatures stimulate the growth and activity of microorganisms that degrade labile organic material and are responsible for methanogenesis. Less gas is produced during colder months, when microbial activity decreases; while more gas is produced during warmer months, when microbial activity increases. Microorganisms responsible for methanogenesis are metabolically active between 4°C and 45°C with an optimal temperature range for methanogenesis between 35°C and 42°C (Zeikus and Winfrey 1976). Subsequent research at numerous sites shows that the majority of sediment gas production occurs in the summer months, during peak temperatures, and drops significantly with seasonal decreases in temperature, typically when surface water temperatures fall below 10°C to 20°C (Adriaens et al. 2009; Blischke and Olsta 2009; Chattopadhyay et al. 2010; Rockne et al. 2010; Sittoni et al. 2015; Viana et al. 2007, 2012, 2015; Yin et al. 2010; Boehme et al. 1996). One study (Viana et al. 2007) indicates more than 95% of annual gas production occurs during the spring, summer, and fall period, when compared to the winter period.

Methanogenesis occurs in sediment, so it is affected more directly by sediment temperature than by surface water temperature. Sediment temperatures are influenced by combined surface water and groundwater temperatures, as the two water masses interact and mix in sediment. As discussed in Section 4.2.4, sediment temperature has been measured during the September 2017 pilot study and for a year during the 2018/2019 FS Part 2 gas ebullition field program.

2.2 Gas Ebullition

Once a gas bubble forms, its combined internal pressure and size induce a stress on the sediment that must exceed the strength of the surrounding sediment and the overburden pressure of the sediment and water column, to fracture the sediment and create a pathway for the gas bubble to move upward through the sediment to the water column and eventually to the water surface. The joint processes of methanogenesis, gas bubble formation, sediment fracturing, and the migration of gas bubbles through sediment are the components of gas ebullition.

The environmental conditions that affect gas ebullition include sediment temperature, sediment strength, depth within the sediment, and water depth. Gas ebullition tends to be more common during seasonally warmer weather; in soft, shallow, organic-rich sediment that is easily fractured; and in either shallow areas or during low water conditions (e.g., low tide) (Joyce and Jewell 2003).

Increasing water depth and hydrostatic pressure increases the amount of methane and other dissolved gases that remain dissolved in sediment porewater, thereby requiring additional gas production to increase the amount of dissolved gas in porewater. Once the higher solubility is reached and the porewater becomes saturated with gas, bubbles may form. This pressure-dependent limitation on bubble formation will increase with water depth and depth below the mudline, as hydrostatic pressure increases. Figure D2-2 shows the change in methane solubility over a 10-meter water depth.

Gas bubble formation is limited not just by hydrostatic pressure and dissolved gas solubility, but also by sediment tensile strength. As gas is generated and a gas bubble begins to form, the gas pressure within the bubble will increase. The gas pressure and gas bubble size combine to induce stress on the sediment. If the stress becomes sufficiently high, a crack will form at the bubble tip and propagate in the sediment. The propagating crack becomes the pathway for gas bubble movement through the sediment. The stress at which the crack forms and propagates is related to the tensile strength of the sediment. The tensile strength of the sediment refers to the sediment capacity to resist fracture and is a characteristic property of the sediment, referred to more generally in this appendix as sediment strength. The sediment tensile strength increases and water content decreases with depth, because the sediment is compressed by both the weight of overlying sediment and hydrostatic pressure from the overlying water column, thus resisting the tensile force exerted by a forming gas bubble. Therefore, soft sediment is expected to experience a relative increase in resistance to fracture near the time of high tide (compared to low tide) due to increasing water depth and hydrostatic pressure associated with the incoming tide (Algar et al. 2011).

2.3 Gas Ebullition-Facilitated NAPL/Contaminant Transport

For gas ebullition-facilitated transport (or flux) of NAPL/contaminants from sediment to surface water to occur, it is necessary to have processes for gas bubble formation and growth, have the gas bubbles overcome combined hydrostatic pressure and sediment strength, and have the gas bubbles pass through a zone(s) of NAPL/contaminants, where the NAPL/contaminants attach to the gas bubbles as the gas bubbles migrate upward. NAPL and particulates with sorbed contaminants may attach to gas bubbles and be transported through the sediment column to the overlying surface water. NAPL that is attached to a gas bubble and is transported to the surface of the water often spreads and forms a sheen. Surface water sheens can subsequently break down by photodegradation, biodegradation, volatilization, and dissolution of sheen constituents into the surface water (see Section 6 of the RI Report).

Similarly, oil-particle aggregates (OPAs) and/or contaminants sorbed to sediment solids may be transported with gas bubbles. An OPA forms due to the aggregation between a suspended oil droplet and suspended particulate matter. When the particles adhere to the oil droplet, the aggregates become denser than water, causing them to sink within the water column and deposit, becoming part of the sediment bed. Following deposition, the OPAs may be resuspended by subsequent gas ebullition that entrains the OPAs (Fitzpatrick et al. 2015). Additional information regarding OPAs is included in Appendix C of the RI Report.

3 FIELD GAS EBULLITION SURVEYS AND PILOT STUDY DISCUSSION

The FESs in 2015 and 2016 were conducted in accordance with the USEPA-approved *Phase 2 Field Sampling and Analysis Plan – Volume 2 Addendum No. 3* (Phase 2 FSAP Volume 2 Addendum No. 3; Anchor QEA 2015) and *Phase 2 Field Sampling and Analysis Plan – Volume 2 Addendum No. 4* (Phase 2 FSAP Volume 2 Addendum No. 4; Anchor QEA 2016). The 2017 pilot study was conducted in accordance with the *Feasibility Study Field Program Work Plan* (Anchor QEA 2017). Section 3.1 summarizes the 2015 and 2016 FES procedures and data collection methods; the 2017 pilot study is summarized in Section 3.2. Data collected during the FESs are reported in the *Phase 2 Remedial Investigation Field Program Data Summary Report* (Phase 2 DSR; see Appendix Bi of the RI Report), and data collected during the pilot study are reported in the *Feasibility Study Field Program Data Summary Report Part 1* (FS DSR Part 1; see Appendix Bii of the RI Report), which document data collection methods and results as well as deviations from the approved field procedures.

3.1 Field Gas Ebullition Survey Approach

FESs were conducted in August 2015 and September 2016 to observe and document apparent gas ebullition and sheens in surface water and to develop an understanding of conditions within the Study Area where gas ebullition is most likely to occur. These studies characterized the presence and extent of gas ebullition-facilitated NAPL/contaminant transport in the Study Area.

The FESs used direct observation of sheens and bubbles on the water surface, and to the extent allowed by the clarity of the water, observation of bubbles rising through the water column to the water surface. Low water clarity has the potential to hinder the ability to observe gas bubbles rising through the water column from the sediment surface. Although the source of gas ebullition cannot be conclusively determined without an observation of the bubble origin, in the absence of an alternative source of bubbles (i.e., aeration system, biota, vessel movement), the observation of a gas bubble was assumed to be representative of "apparent gas ebullition" originating from the sediment surface. However, there are a number of potential sources of gas bubbles observed on the surface of the water within the Study Area. Sheens were differentiated during the FESs into dynamic sheens and static sheens. Dynamic sheens include sheen blossoms (sheens appearing with a breaking gas bubble) and expanding sheens (sheens appearing with no apparent gas bubble observed). Static sheens float on the water surface into the observation area. Potential static sheen sources included the following categories: seepage from bulkheads, floatables, outfall discharge, surface scum, dynamic sheens generated outside the observation area, vessel movements that result in NAPL discharges from engine/bilge/deck runoff and resultant sheens, and unknown sources.

3.1.1 Survey Timing and Areas

Although the gas ebullition process is sensitive to many factors (see Section 2), the two key factors considered while selecting the timing of the field surveys were temperature and tidal elevation. The 2015 study included two surveys during low tide and one survey during high tide. The 2016 study included four surveys during low tide.

"Spring tides" refer to the approximately 5- to 7-day periods that occur near the times of a full moon and a new moon. During those times, the alignment of the earth, moon, and sun results in relatively higher gravitational forces on the earth compared to other phases of the average 29.5-day lunar cycle. The result of this higher gravitational force is higher high tide and lower low tide water elevations (compared to water elevations averaged over the lunar cycle). Neap tides are of similar duration and also occur twice per lunar cycle, midway between the full and new moons, resulting in lower high tides and higher low tides compared to average water elevations. Intermediate phases of the tidal cycle (between spring and neap tides) have water elevations closer to average. Larger tidal ranges (difference in water elevation between consecutive high and low tides) and lower low tide water elevations coincide with more extensive gas ebullition.

The decision to perform the surveys during low tide was based on the expectation that gas ebullition would be most active near the time of low tide, when the water pressure was lowest compared to the rest of the tidal cycle. Additionally, surveys were performed when tidal ranges were largest, when possible. The high tide survey during the 2015 FES was intended to evaluate the effect of increased water pressure associated with higher water elevations on FES observations. Additionally, the 2015 and 2016 surveys were performed in August and September, respectively, when seasonal water temperatures were near their maximum and gas ebullition would be expected to be more active than at other times of the year, when water temperatures are lower. Similar field surveys were conducted in the two pilot study areas in 2017 and are described in Section 3.2. The dates of each survey, tide elevations at the time of the surveys, tidal height difference (i.e., change in elevation from preceding high tide to low tide elevation), and average surface water temperatures are summarized in Table D3-1.

To capture the range of geomorphic, hydrologic, and hydrodynamic conditions in the Study Area, the FESs were conducted in areas that exhibited the following characteristics:

- A range of geomorphic settings that included the tributaries, the main stem of Newtown Creek, and CM 2+
- A range of water depths to assess the effect of water depth (i.e., hydrostatic pressure) on gas ebullition
- Locations near areas of higher concentrations of organic material within the upper 5 feet of sediment
- A range of commercial vessel traffic frequencies to assess the effect of propeller wash and vessel wake on disturbance of sediment and appearance of gas bubbles in surface water
- A range of NAPL observations in the sediment (see Appendix C of the RI Report for a detailed discussion of potential NAPL observations and shake test results)
- Locations where anecdotal (i.e., not characterized in detail or quantified) observations of gas bubbles had been previously reported. The 2016 survey included locations where apparent gas ebullition was documented in 2015
- The 2015 and 2016 surveys avoided locations near active aeration systems to avoid misidentifying aeration system generated bubbles as apparent gas ebullition

Based on the previously mentioned parameters, the areas identified for surveying, as outlined in the USEPA-approved work plans, included the following:

- 2015 FES
  - Newtown Creek, from CM 0.19 to 0.5, CM 0.67 to 0.83, CM 0.9 to 1.36, and CM 1.6 to 1.94
  - Dutch Kills

- Maspeth Creek
- Turning Basin
- East Branch
- English Kills

- 2016 FES
  - Newtown Creek, from CM 0.57 to 1.94
  - Dutch Kills
  - Maspeth Creek
  - Turning Basin
  - East Branch
  - English Kills
  - Whale Creek

The 2015 and 2016 FESs included visual observations of the water surface over approximately 80% of the 171-acre Study Area for the presence of sheen and gas bubbles (see Figure D3-1). A summary of the environmental conditions in each survey area is provided in Table D3-2.

3.1.2 Survey Methods and Procedures

The FESs were performed concurrently in each of the survey areas, using multiple survey vessels under a range of tidal conditions. The 2015 field survey included five separate field crews (one staff each), and the 2016 field survey included 10 separate field crews (two staff each) in small- to medium-sized skiffs or work boats. The field survey included field logging of visual observations, and video and still photography of observations (provided in Appendix B of the RI Report) of apparent gas ebullition and sheens. The movements of the survey vessels over the course of the survey were tracked through the collection of continuous coordinate data. In addition, locations where visual evidence of sheens or apparent gas ebullition were observed were mapped either by using differential global positioning system equipment with measurements to estimate the extent of the area, or by hand drawing onto maps (tablets or hard copy).

To avoid disturbing the sediment, the surveys were performed from small survey vessels that moved very slowly, without the use of anchors. Vessel speed did not exceed 2.5 knots in the main stem, where surface water was deeper; and it did not exceed 1 knot in areas where water was shallower and there was a greater potential for the survey vessel to disturb the surface sediment. When visual evidence of apparent gas ebullition was observed during vessel movement, the vessel would stop to allow for detailed observation and documentation.

The following survey conditions were deemed necessary/optimal for collecting accurate observations of apparent gas ebullition:

- Daytime hours for visibility
- Fair weather conditions for visibility and to accommodate safe, stable vessel operation
- Limited vessel (i.e., commercial, recreational, and survey) traffic to avoid interfering with survey operations
- No disturbance of the sediment (e.g., anchoring, survey vessel movements, wakes, and propeller scour) to avoid interference with survey observations and measurements
- Shut down of the aeration system a minimum of 24 hours prior to and during the survey to minimize the appearance of air bubbles associated with the aeration system that could not be distinguished from apparent gas ebullition

In English Kills, the operating status of the aeration system was recorded, and the location of the bubbles apparently originating from the aeration system was mapped relative to survey observations/measurements. In addition, the generation of bubbles by biota was noted, if water visibility allowed. In most locations, low water visibility allowed observation of gas bubbles only within several inches to 1 to 2 feet of the water surface. This limitation would not allow observation of bubble sources below these depths (e.g., biota or the aeration system). The environmental conditions during the time of the survey were documented in field logs (provided in Appendix B of the RI Report) and are summarized in Section 4.1.3.

During each survey where visual evidence of apparent gas ebullition or sheen was observed, the location, type of observation, approximate size of the area, frequency, sheen distribution/color/dimension/structure, and gas bubble distribution were recorded using the terminology included in the Phase 2 FSAP Volume 2 Addendum No. 3 (Anchor QEA 2015) and SOP NC-38 – Field Gas Ebullition Survey and provided in Sections 3.1.2.1 and 3.1.2.2. Additionally, surface water quality monitoring and documentation of environmental conditions were conducted as summarized in Sections 3.1.2.3 and 3.2.3.2, respectively. The

Phase 2 DSR and FS DSR Part 1 (see Appendices Bi and Bii of the RI Report) provide additional detail regarding survey methods and procedures.

3.1.2.1 Sheen Observations

Sheen observations, including distribution, structure, and color, were recorded. Sheens that develop on the water surface are classified as dynamic sheens (sheen blossoms with a breaking gas bubble or expanding sheens without a breaking gas bubble), whereas static sheens float on the water surface into the observation area. The frequency of dynamic sheens (number of observations over a given period of time) was recorded. Figure D3-2 presents photographs of example static and dynamic sheen observations.

Observation and classification of sheens was conducted to identify areas where NAPL/contaminants that may be transported from sediment to surface water via gas ebullition form a sheen on the surface of the water. However, sheens observed on the water surface do not always originate from gas ebullition and may be related to releases from commercial or recreational vessels, point source discharges, or other sources. Table D3-3 summarizes the terminology used in sheen observations and classifications.

After observations of static sheens had been made, an attempt to identify the potential source of the static sheen was conducted. Potential sources of static sheen included the following: seepage from bulkheads, floatables, outfall discharge, surface scum, dynamic sheens generated outside the observation area, commercial or recreational vessel movements that result in stirring up surface sediments, and unknown sources.

3.1.2.2 Apparent Gas Ebullition Observations

Visual observation of gas bubbles on the water surface were recorded (see Figure D3-3 for example gas bubble observations). There are a number of potential sources of gas bubbles observed on the surface of the water within the Study Area. These can include (but are not limited to) the aeration system, biota, vessel (commercial, recreational, survey) movement, and gas ebullition associated with the sediment. Each of these potential sources has been observed in the Study Area and, with the exception of biota, can be a significant source of bubbles on surface water.

During the surveys, observations of apparent gas ebullition were only recorded if a bubble was seen coming to the water surface and if the bubble was not already floating at the surface. In some cases, bubbles originating from biota (e.g., crabs and fish) were observed rising through the water column. In those cases, because the source of the bubbles was identifiable, the observation was recorded but not considered to be apparent gas ebullition. In areas where low water clarity limited the degree to which bubbles could be observed rising through the water column, the appearance of bubbles on the surface of the water was conservatively inferred as the presence of gas ebullition in sediment, unless another potential source of bubbles (e.g., boat traffic or aeration system operation) was observed nearby.

When gas bubbles were observed, the frequency over a 5-minute period and spatial distribution were noted using the nomenclature summarized in Table D3-3.

3.1.2.3 Environmental Conditions

Surface water quality, weather conditions, and water surface elevations (WSEs) were recorded during each survey. Surface water quality measurements including temperature, salinity, and water clarity (2015 FES only), were recorded prior to and during each survey using a sonde and Secchi disk at the stations depicted in Figure D3-4. At least one water quality station was located within each FES area.

After each survey was completed for an area, post-survey water quality measurements were collected, and the water depth was measured using a lead line. Lead line water depth measurements were collected after the surveys to avoid disturbing the sediment and potentially influencing apparent gas ebullition observations. WSEs were recorded from Study Area tidal gauges, and atmospheric temperature and pressure were recorded from the project weather station located at the field facility.

3.2 NAPL/Contaminant and Gas Flux Pilot Study Approach

Following the completion of the 2015 and 2016 FESs, USEPA indicated that additional characterization of gas ebullition in the Study Area was needed and directed that upward fluxes of gas and NAPL/contaminants from the mudline to the overlying surface water be estimated during the FS field work (USEPA 2016). A pilot study gas ebullition program

(FS Part 1 field activities) was conducted in September 2017 to develop and test methodologies for measuring upward fluxes of NAPL/contaminants and gas for use in the 2018/2019 FS gas ebullition field program. Additionally, the pilot study further evaluated the effect of site-specific environmental conditions, such as surface water tidal elevations, surface water and sediment temperatures, and weather conditions on NAPL and gas flux from the mudline to the overlying surface water.

Specific pilot study objectives included the following:

1. Evaluate the representativeness of the pilot study gas ebullition-facilitated NAPL/contaminant flux measurements by comparing the consistency of the flux measurements collected using different sampling methodologies and by relative comparison of gas ebullition-facilitated NAPL/contaminant and gas flux measurements to qualitative visual observations of sheen blossoms and gas bubbles.
2. Evaluate the ability of the flux measurement equipment to withstand Study Area conditions (e.g., propeller wash associated with commercial or recreational vessel travel, tides, and current velocities in the vicinity of the CSOs) and to operate in a consistent and reliable manner.
3. Implement the full range of potential sampling elements that might be used in the FS gas ebullition field program (FS Part 2 field program), including visual observations; gas ebullition-facilitated NAPL/contaminant flux and gas flux measurements; gas, surface water, porewater, surface sediment, and subsurface sediment sampling; and sediment temperature profiling. Evaluate the ability of the resulting data to satisfy the objectives of the FS gas ebullition field program.

The pilot study included multiple elements to achieve these objectives, which are described in the following sections.

3.2.1 Pilot Study Timing and Locations

The pilot study was conducted during a spring tide in September 2017 when water temperatures were near average annual maximums. The NAPL/contaminant and gas flux measurements were conducted over a 4-day window; however, due to tidal surges from Hurricane Jose, the Dutch Kills flux chambers were retrieved 1 day early.

The pilot study was conducted at two stations located at the head of Dutch Kills (Station DK052) and in the Turning Basin (Station NC342) (see Figure D3-5). These sampling station locations were selected because sheen blossoms and gas bubbles were observed at these locations during the 2015 and/or 2016 FESs. Additionally, the observations and conditions at the two locations varied, allowing evaluation of the effect of the differing conditions on the gas ebullition process. These conditions include water depth, organic material content, commercial and recreational vessel impacts, proximity to point source discharges, and sediment NAPL observations.

3.2.2 Flux Chamber Methods and Procedures

Near-bottom flux measurements were collected using flux chambers designed to capture the upward flux of gas ebullition-facilitated NAPL/contaminants and gas from the sediment directly beneath the chamber. Flux chamber sampling was conducted as summarized in the remainder of this section and following procedures in SOP NC-43 – NAPL/Contaminant and Gas Collection Chamber Measurements (see Figure D3-6 for photographs of flux chamber equipment). Additionally, surface-based measurements (sheen nets and gas tents positioned close to [but not directly over] the top of the near-bottom flux chambers) were conducted and evaluated as potential methodologies to measure gas and gas ebullition-facilitated NAPL/contaminants, as detailed in the FS DSR Part 1 (see Appendix Bii of the RI Report). Following the pilot study and in consultation with USEPA, the near-bottom flux measurements were determined to be the preferred alternative to be carried forward into the 2018/2019 FS gas ebullition field program (Anchor QEA 2018). The pilot study surface-based NAPL/contaminant and gas flux methods and results are provided in the FS DSR Part 1 (see Appendix Bii of the RI Report).

Flux measurement equipment was deployed at each pilot study sampling station using divers and secured to frames spudded into the sediment, with the bottom of each chamber positioned approximately 1 foot above the mudline. To minimize disturbance of the sediment under the flux chamber, the spuds were offset from the flux chamber by approximately 2 feet and installed in sediment at the sampling point at least 1 day prior to conducting measurements. One flux chamber (DK052-C) was inadvertently moved during monitoring and was reinstalled.

Flux chambers were equipped with a reservoir at the top where gas could accumulate, with glass wool traps positioned below to collect NAPL/contaminants that were entrained in (or coating the surface of) gas bubbles that entered the flux chamber from below. The glass wool traps may have also captured particulates suspended in the water column during flux chamber placement by the divers (divers reported disturbance to the sediment surface during flux chamber placement). As such, the NAPL/contaminants captured by the glass wool may have included NAPL/contaminants from sources other than gas ebullition occurring below the flux chamber and may overestimate the flux of NAPL/contaminants from the mudline to the overlying surface water that is facilitated by gas ebullition. The mass of NAPL/contaminants and volume and mass of gas collected were quantified, and samples of the glass wool and gas were analyzed to characterize NAPL/contaminant and gas chemistry (see Section 4.2).

To assess the potential for high bias from NAPL/contaminant constituents present in the surface water that adheres to the glass wool, a control sampler was attached to the flux chamber. This control sampler measured NAPL/contaminant mass in the water column that contacted the control sampler, but not from gas ebullition originating below the flux chamber. This allows differentiation between NAPL/contaminants that originate in the water column (also potentially including NAPL/contaminants released from ebullition that did not occur directly below the flux chamber, if any) from those originating from gas ebullition directly below the flux chamber.

3.2.3 Supplemental Data Collection Methods

Visual observations of sheens and apparent gas ebullition and environmental conditions were recorded during flux chamber deployment to supplement the NAPL/contaminant and gas flux measurements. The methods and procedures used to collect this supplemental data are summarized in Sections 3.2.3.1, 3.2.3.2, and 3.2.3.3. Additionally, sediment, porewater, and surface water samples were collected as part of the pilot study and are briefly summarized in Sections 3.2.3.1, 3.2.3.2, and 3.2.3.3. The methods and results for those programs are included in the *Feasibility Study Field Program Work Plan and Field Sampling Analysis Plan Addendum No. 2: Gas Ebullition Field Program* (FS FP Work Plan and FSAP – Addendum No. 2; Anchor QEA 2018).

3.2.3.1 Visual Observations

During the pilot study, visual observations of sheens and gas bubbles were recorded near the two pilot study sampling stations where flux chambers were deployed (see Figure D3-5). Visual observations near flux chamber deployment locations were limited compared to the areas farther from the equipment to lessen the potential for disruption to the in situ sampling equipment from survey vessel operation. Generally, visual observations during the pilot study were made using methods similar to those used during the FESs (as described in Section 3.1.2), in areas within and surrounding the sampling stations where gas ebullition-facilitated NAPL/contaminant flux and gas flux measurements were collected. Visual observations were targeted for a period of up to 6 hours around low tide, dependent on available daylight and logistical constraints (i.e., the low clearance of the bridge at the entrance to Dutch Kills). Pilot study visual observations were limited to 2 days in Dutch Kills and 3 days in the Turning Basin, due to weather and surface water elevation constraints.

3.2.3.2 Environmental Conditions

Weather conditions (including air temperature, barometric pressure, wind, and precipitation), surface water temperature, WSEs and water quality data, commercial and recreational vessel traffic data, and sediment temperature were recorded during the pilot study and are provided in Part 1 of the FS DSR (see Appendix Bii of the RI Report).

Weather data collected at the field facility and Turning Basin weather stations during the pilot study included air temperature, barometric pressure, wind speed and direction, and precipitation. Near-bottom surface water quality parameters (including water temperature, salinity, oxidation reduction potential [ORP], and turbidity) were collected during installation and retrieval of the NAPL/contaminant and gas flux chambers, at the start and end of visual observations, and during surface water sample collection. Commercial and recreational vessel track data were collected during the pilot study using the Maritime Mobile Service. Sediment temperature sensors were placed within each sampling station at depths of 1, 2, 3, 4, 5, 7.5, and 10 feet below the mudline, and temperature data were recorded every 30 minutes for a month surrounding the duration of the pilot study.

3.2.3.3 Sediment, Porewater, and Surface Water

Sediment and porewater samples were collected at pilot study stations to evaluate the depth range below the mudline of active methanogenesis in the sediment, recognizing that the zone of active methanogenesis likely extends deeper than the zone of active gas ebullition, for reasons discussed previously in Section 2.2. A total of three surface sediment samples (0 to 2.5, 7.5 to 10, 15 to 17.5 cm) and seven subsurface sediment samples (20 to 40, 50 to 70, 80 to 100, 110 to 130, 140 to 160, 220 to 240, 285 to 305 cm) were collected at each sampling station for bulk sediment analysis and porewater analysis in surface sediment intervals.

Pilot study surface water monitoring and sample collection was performed to evaluate the potential surface water/porewater interaction and the potential for surface water to influence porewater chemistry and gas ebullition-facilitated NAPL/contaminant flux and gas flux. Two near-bottom surface water samples were collected prior to sediment sampling at each pilot study station, and the results are presented in Section 2.2.3.3 of the FS FP Work Plan and FSAP – Addendum No. 2 (Anchor QEA 2018).

4 RESULTS OF THE FIELD GAS EBULLITION SURVEYS AND PILOT STUDY

This section presents the results of the FESs and pilot study following the methods outlined in Section 3. The FES results are provided in Section 4.1 and the pilot study results are included in Section 4.2.

4.1 Field Gas Ebullition Surveys Results

This section presents the results of the 2015 and 2016 FESs, including a summary of the visual observations of sheen and apparent gas ebullition and environmental conditions, including surface water quality measurements, WSEs, weather, and commercial and recreational vessel activity throughout the Study Area.

4.1.1 Survey Transects

Figures D4-1a through D4-1c present the survey vessel transects for the three 2015 survey events, and Figures D4-1d through D4-1g present the survey transects for the four 2016 survey events. Vessel transects show that surveying was performed in all the target areas identified in the Phase 2 FSAP Volume 2 Addenda Nos. 3 and 4 (Anchor QEA 2015, 2016) with coverage designed to characterize the extent of gas ebullition-facilitated NAPL/contaminant and gas flux transport.

The surveys did not include areas within approximately 100 feet of the operating aeration system. During the 2015 surveys and the 2016 Low Tide Survey No. 4, the aeration system was operating in both upper and lower English Kills. However, during the remaining three 2016 surveys, the aeration system in upper and lower English Kills was not operating. English Kills shoreline areas (i.e., areas located more than 100 feet from the operating aeration system) were surveyed during all seven survey events.

4.1.2 Visual Observation Results

Observations of surface water sheen and apparent gas ebullition during the FESs are discussed in Sections 4.1.2.1 and 4.1.2.2, respectively. Observations of sheen and bubbles include both individual point observations (e.g., one sheen blossom) and observations within subareas (shown as polygons in figures) where observations were consistent (e.g., same gas bubble rate), and the extent of the area with consistent observations was mapped. Counts of the number of observations are provided in Sections 4.1.2.1 and 4.1.2.2 along with figures depicting the extent of these observations. Table D4-1 presents a summary of the sheen and gas bubble observations; actual survey locations, survey collection dates, water depths, and survey observations are included in Appendix Bi of the RI Report.

4.1.2.1 Sheen Observations

Sheens, including static sheens (those which floated into the observation area from outside) and dynamic sheens (those generated within the observation area), were observed in defined portions of each survey area, with more individual observations in 2016 than 2015 (individual observations refer to instances where field teams stopped to record any type of sheen observation). Table D4-1 includes summary counts of sheen observations by survey area. Figure D4-2a summarizes sheen observations by static and dynamic sheen for the 2015 FES, and Figure D4-2b summarizes the observations for the 2016 FES.

In 2015, sheens were observed in localized areas during each survey with the majority of the spatial coverage from static sheens, rather than dynamic sheens (static sheens comprised 99% of the area with observed sheens). Only 8% of all sheen observations (including dynamic and static sheens) consisted of sheen blossoms (4 of 51 observations). Sheen blossoms were observed only at the head of English Kills and in the Turning Basin during the low tide surveys, with no sheen blossoms observed during the high tide survey.

Sheens were observed more widely across the Study Area during the 2016 surveys and predominantly consisted of static sheens, rather than dynamic sheens (static sheens comprised 78% of the area with observed sheens and 77% of the observations). Although sheen blossoms were seen throughout portions of each of the survey areas during the 2016 field survey, the largest numbers of sheen blossoms were observed in English Kills, Dutch Kills, East Branch, and the Turning Basin. Sheen blossom rates at the heads of English Kills, Maspeth Creek, and Dutch Kills were highest during the 2016 Low Tide Survey No. 4 (rainfall event). Sheen blossoms ranged in size, with larger blossoms observed on average in the Turning Basin and English Kills.

Expanding sheens were not observed during the 2015 survey, while 22 instances were observed in 2016, predominantly in English Kills. The locations where sheen blossoms and expanding sheens were observed during the 2015 and 2016 FESs are shown in Figure D4-3. Dynamic sheens were primarily sheen blossom observations rather than expanding sheens (sheen blossoms comprised 92% of dynamic sheens).

During the 2016 survey, a sheen seep was observed originating from the Waste Management of NY/Steel Equities (formerly Pratt Oil Works; *Data Applicability Report* No. 56) bulkhead. In 2019, a sheetpile wall was installed along the bank in the area of the reported seep observation for the purpose of controlling any further seeps from this area.

When a static sheen was noted during the surveys, an effort was made to identify a potential sheen source. Floatables, surface scum, and commercial and recreational vessel movement likely account for 33% of sheen observations in 2015 and 11% in 2016. Additionally, in 2016, static sheen was observed near bulkheads and outfalls. For example, on September 19, 2016, sheens were observed by NCG originating from three outfalls: NCB-683, NCQ-637, and BB-609 or BB-610. However, while seemingly unlikely because the sheens tend to dissipate over time, because these outfalls are submerged at high tide, static sheen could have entered the outfall due to tidal movement prior to the observation of the sheens originating from these outfalls. Therefore, these observations of potential sheen source are considered circumstantial and not confirmation of a source.

4.1.2.2 Gas Bubble Observations

During the 2015 field survey, 45 observations of gas bubbles were recorded. During the 2016 field survey, 924 observations of gas bubbles were recorded. Gas bubbles were observed in all survey areas during the 2016 field survey, but gas bubbles were only observed in the main stem of the Study Area (from CM 0.9 to 1.36 and CM 1.6 to 1.94), in each of the tributary survey areas, and in the Turning Basin during the 2015 field survey. Gas bubbles were not observed in two of the main stem survey areas (CM 0.19 to 0.50 and CM 0.67 to 0.83) during the 2015 field survey. Table D4-1 summarizes the observations of gas bubbles by survey area. Figure D4-4a summarizes gas bubble observations for the 2015 FES, and Figure D4-4b summarizes the observations for the 2016 FES.

Apparent gas ebullition was infrequent during the high tide event in 2015 compared to the low tide events in both 2015 and 2016 and was only observed in Dutch Kills (two locations) and East Branch (one location). More than 90% of the observations of apparent gas ebullition in 2015 occurred during the two low tide surveys, so low tide conditions were targeted in the 2016 FES. Apparent gas ebullition observations were more frequent during the 2016 surveys (840 observations) than during the 2015 surveys (37 observations) and were generally similar during each day of the 2016 FES.

In addition to gas bubbles from apparent gas ebullition, gas bubbles were also observed as the result of the aeration system, biota (fish or crab), commercial and recreational vessel movements, or outfalls. In 2015, 18% of gas bubble observations in the areas surveyed were associated with other potential sources (e.g., aeration system, biota), and during the 2016 FES, 9% were associated with other potential sources. The remaining bubble observations (including 82% of the 2015 FES and 91% of the 2016 FES observations) were attributed to apparent gas ebullition.

In general, apparent gas ebullition appeared minimal in the first 2 miles of the Study Area survey areas and more frequent in the tributaries and in portions of CM 2+. During the 2015 field surveys, the largest areas of apparent gas ebullition were observed in Dutch Kills, Maspeth Creek, East Branch, and the Turning Basin during the low tide surveys. The most frequent gas ebullition during the 2016 field surveys was observed in Dutch Kills, East Branch, the Turning Basin, and English Kills. The extent, frequency, and distribution of apparent gas ebullition corresponds to the tidal cycle with more apparent gas ebullition observed during low tide with the associated reduction in hydrostatic pressure experienced by the sediment during low tide events (see Section 5.1.2.2).

4.1.3 Environmental Conditions

In general, observations of gas bubbles and sheens during the FESs were not adversely impacted by environmental conditions. With the exception of 1 day of rainfall and the generally low water clarity associated with that event, which prevented the ability to see below the top 1 to 2 feet of water and identify the source of most gas bubbles, survey observations and measurements were not obscured. Environmental factors that could affect the ability to see and quantify apparent gas ebullition included surface water clarity, precipitation, wind speed and direction, and the presence of biota.

Environmental factors that influence and can alter the gas ebullition process include tidal fluctuations, weather conditions other than precipitation and wind (barometric pressure and air temperature, to the extent water temperature is affected), and water/sediment temperature. Additionally, anthropogenic factors such as commercial and recreational vessel movements and/or aeration system operation could obscure observations of apparent gas ebullition and sheen. Environmental conditions data are provided in Appendix B of the RI Report.

Sections 4.1.3.1 through 4.1.3.4 provide the results of various environmental conditions monitored during the 2015 and 2016 surveys.

4.1.3.1 Surface Water Quality Data

Surface water quality data were collected within the survey areas approximately 3 feet above the mudline before, during, and after the surveys. Actual surface water profiling locations are shown in Figure D3-4.

As shown in Figure D4-5a and D4-5b, surface water temperature and salinity were generally consistent between surveys for the 2015 and 2016 events. Based on the surface water temperature data collected in the Study Area during the Phase 1 RI, the FESs were performed at the peak annual Study Area surface water temperatures that occur between late July and early September (see Figures D4-6a and D4-6b).

The relatively small variability (compared to seasonal ranges) in water quality measurements suggests that the water quality parameters monitored are not likely factors influencing any changes observed in apparent gas ebullition between the various rounds of data collected.

4.1.3.2 Tidal Conditions

WSEs from the Hunter's Point National Oceanic and Atmospheric Administration (NOAA) water elevation recording station ranged from 0.5 to 0.7 foot mean lower low water (MLLW) at low tide for the 2015 FES and from -0.2 to -0.4 foot MLLW for the 2016 FES (see

Figures D4-7a and D4-7b, respectively). Within the Study Area (Hunter's Point tidal elevations), annual low tide WSEs range from -1.2 to 1.3 feet MLLW with the WSEs during these FESs representing the 22nd and 83rd percentiles for 2015 and 2016, respectively. Tidal difference, or the difference in WSE between high and low tide, was 3.6 feet for the 2015 FES and ranged from 5.1 to 5.6 feet with an arithmetic average of 5.5 feet for the 2016 FES (see Figures D4-8a and D4-8b, respectively). The tidal ranges represent the 25th and 91st percentiles for 2015 and 2016, respectively.

4.1.3.3 Weather Conditions

Weather conditions data for each survey included air temperature, barometric pressure, wind speed, and wind direction and are provided in Figures D4-9a and D4-9b. Individual results are provided in Appendix B of the RI Report. With the exception of rainfall that occurred leading up to and during 2016 Low Tide Survey No. 4, environmental conditions were generally similar during the 2015 and 2016 field survey events and did not appear to influence survey observations or gas ebullition. The rainfall occurred in the hours before the beginning of 2016 Low Tide Survey No. 4 and continued during the first half of the survey. During that rain event, 0.78 inch of rain was recorded at the National Weather Service Daily Climate Report for LaGuardia, New York.

4.1.3.4 Commercial and Recreational Vessel Impacts

According to Automatic Identification System (AIS) data,[3] there was minimal vessel traffic during the surveys. Four sheen observations (8% of all observations) were associated with vessel movements (i.e., propeller wash resuspending the sediment) during the 2015 field survey, and 27 sheen observations (3% of all observations) were associated with vessel movements during the 2016 field survey. Overall, vessel movements were limited and did not likely influence survey observations.

[3] These data are publicly available from marinetraffic.com for commercial and recreational vessels equipped with and operating AIS systems.

4.2 NAPL/Contaminant and Gas Flux Pilot Study Results

This section presents the results of the September 2017 NAPL/contaminant and gas flux measurement pilot study. During the pilot study, NAPL/contaminant and gas flux measurement equipment and methods were designed, tested, and evaluated for use in the 2018/2019 FS Part 2 gas ebullition field program. A summary of flux chamber NAPL/ contaminant results is provided in Section 4.2.1; gas results are provided in Section 4.2.2; additional associated surveys documenting visual observations are provided in Section 4.2.3; environmental condition results are provided in Section 4.2.4; and sediment, porewater, and surface water results are provided in Section 4.2.5. Detailed results from the pilot study are provided in the FS DSR Part 1 (see Appendix Bii of the RI Report) and the FS FP Work Plan and FSAP – Addendum No. 2 (Anchor QEA 2018).

4.2.1 NAPL/Contaminant Flux Chamber Results

NAPL/contaminant flux samples were obtained from three flux chambers in Dutch Kills and five flux chambers in the Turning Basin using glass wool in collection chambers on top of the flux chambers. Glass wool samples were analyzed for mass of NAPL, polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs), extractable petroleum hydrocarbons, and oil and grease to evaluate the flux of NAPL/contaminants. A summary of the flux chamber sampling program is included in Table D4-2.

NAPL flux results among replicates ranged from not detected to 2.1 milligrams per square meter per day (mg/m^2/day) from the two unmoved flux chambers in Dutch Kills (the flux chamber that was inadvertently moved [DK052-C] had a NAPL flux of 2.5 mg/m^2/day) and from 0.46 to 5.0 mg/m^2/day from the five flux chambers in the Turning Basin. The NAPL mass measured in the flux chamber and control sampler glass wool samples and used to calculate NAPL flux is shown in Figure D4-10. Analytical results and flux calculations are provided in Appendix Bii of the RI Report and summarized in Table D4-3.

Control sampler NAPL mass ranged from not detected to 0.4 milligram (mg) in the two unmoved Dutch Kills flux chambers and 0.24 to 0.8 mg in the five Turning Basin flux chambers. The control sampler NAPL mass had an arithmetic average of 42% (Dutch Kills, not including DK052-C) and 30% (Turning Basin) of the arithmetic average mass captured in flux chamber glass wool per station. Based on these results, combined with the contact between surface water and flux chamber sampling media, NAPL/contaminant flux measurements may be biased high by the potential inclusion of NAPL/contaminants in surface water and from sources other than gas ebullition (i.e., particulates suspended in the water column by sampling activities) directly beneath the flux chamber in the glass wool sampling media.

4.2.2 Gas Flux Chamber Results

Gas samples were recovered from three flux chamber samplers in Dutch Kills and five flux chamber samplers in the Turning Basin. Samples were collected at the end of the deployment period and processed in the field facility. Gas samples were analyzed for chemical composition to assess gas ebullition processes that generated the gases and for carbon isotopes of methane and carbon dioxide to evaluate carbon sources and the potential depth range for gas ebullition.

At the Dutch Kills station, gas flux ranged from 0.25 to 0.88 liter per square meter per day ($L/m^2/day$) among the two unmoved replicates with an arithmetic average of 0.57 $L/m^2/day$ (DK052-C had a gas flux of 2.1 $L/m^2/day$). Gas fluxes in the five Turning Basin replicates were lower than in Dutch Kills, ranging from 0.04 to 0.21 $L/m^2/day$ with an arithmetic average of 0.10 $L/m^2/day$. Figure D4-11 presents the gas volume flux measurements. Analytical results and flux calculations are provided in Appendix B of the RI Report and summarized in Table D4-4.

Overall, relatively consistent gas chemical composition was observed among replicates at each station (see Figure D4-12a). Higher methane content was observed in Dutch Kills than in the Turning Basin (see Figure D4-12b). In Dutch Kills, methane content in the unmoved flux chambers ranged from 71% to 76%, with an arithmetic average of 74% (DK052-C methane content was 84%). In the Turning Basin, methane content ranged from 11% to 40%, with an arithmetic average of 23%. The methane content in Dutch Kills samples is more consistent with methane concentrations measured in gas samples collected from other sediment sites where gas ebullition is active (Casper et al. 2000; Huttunen et al. 2001; Viana et al. 2011) than the methane content in the Turning Basin samples.

Nitrogen content was considerably higher in samples collected at the Turning Basin station, ranging from 48% to 70% with an arithmetic average of 61%, whereas in Dutch Kills, nitrogen content in the unmoved flux chambers ranged from 17% to 22% with an arithmetic average of 19% (see Figure D4-12a).

Gas flux chamber samples were submitted for analysis of carbon isotopes contained in carbon dioxide and methane. A summary of the results is provided in Table D4-4 and Figures D4-13 and D4-14.

4.2.3 Visual Observation Results

The 2017 pilot study visual observations, including sheen and gas bubble observations, were compared to the quantitative NAPL/contaminant and gas flux measurements to identify a relationship between flux measurements and surface-based observations.

More sheen blossoms were observed in the Turning Basin than in Dutch Kills, consistent with comparably higher NAPL/contaminant mass results in the Turning Basin flux chambers. Additionally, more gas bubbles were observed in Dutch Kills than in the Turning Basin, consistent with comparably higher gas volume collection in Dutch Kills flux chambers. These results indicate that visual observations of sheen blossoms and gas bubbles were generally consistent with gas ebullition-facilitated NAPL/contaminant flux and gas flux measurements.

Gas ebullition began approximately 2.5 hours prior to, through 1.5 hours after, low tide, with the maximum gas ebullition rate observed within a 1-hour window around low tide and steep drop offs on either side of the low tide window. The duration of active sheen blossoms and gas bubbles differed slightly between the two locations, limited to 4 hours around each low tide at the Dutch Kills station and 5 hours around each low tide at the Turning Basin station. The visual observation periods included observations outside (i.e., before and after) these windows with no/minimal sheen blossoms and gas bubbles observed. This confirms that the daily period of active gas ebullition occurs in a relatively brief time window around the low tides.

Overall, visual observations of apparent gas ebullition made during the 2017 pilot study are consistent with those made during the 2015 and 2016 FESs.

4.2.4 Environmental Conditions

Sections 4.2.4.1 through 4.2.4.5 provide the results of various environmental conditions including surface water quality data, WSEs, weather conditions, commercial and recreational vessel impacts, and sediment temperature. Hurricane Jose was located more than 200 miles off the northeastern United States seaboard and trended generally toward the northeast during the pilot study. Effects from the storm were limited to increased winds through most of the pilot study and elevated WSEs due to storm surge. The increased winds made maneuvering survey vessels more difficult, and the surge and resulting increased WSEs likely suppressed gas ebullition relative to predicted WSEs. However, the pilot study objectives were achieved despite these impacts. Environmental conditions data are provided in Appendix B of the RI Report.

4.2.4.1 Surface Water Quality Data

Surface water quality data including water temperature, salinity, conductivity, ORP, and turbidity are presented in Figure D4-15. The data from the pilot study water quality monitoring were consistent with the RI dataset, and surface water temperatures indicate that the average surface water temperature was 22.5°C compared to the peak annual surface water temperature of approximately 25°C (see Figure D4-16).

4.2.4.2 Tidal Conditions

WSEs at the Hunter's Point NOAA station ranged from 0.4 to 0.7 foot MLLW at low tide (see Figure D4-17) representing the 44th percentile of annual low tide WSEs in the Study Area. Storm surges caused the WSEs to rise to an arithmetic average of 0.9 foot greater than the predicted tide level and resulted in WSEs similar to those observed during the 2015 FES. Tidal differences ranged from 4.7 to 5.1 feet with an arithmetic average of 4.8 feet (see Figure D4-18) representing the 74th percentile of tidal differences.

4.2.4.3 Weather Conditions

Weather conditions for each survey, including air temperature, barometric pressure, wind speed, and wind direction are provided in Figure D4-19. Individual results are provided in Appendix B of the RI Report. Wind had the greatest impact on the pilot study with gusts ranging up to 13.3 miles per hour and an arithmetic average wind speed of 5.3 miles per hour. The wind impacted visual observations, but had no observable impacts on flux chambers.

4.2.4.4 Survey Vessel Impacts

No commercial or recreational vessel impacts were observed. However, the 50-foot-diameter configuration within which the placement and operation of the flux measurement equipment, divers, surface-based flux monitoring vessels, and visual observation boats were operating did have impacts on the study. Although pilot study boats were operated to minimize impacts, the large number of boats in the small sampling station areas created waves and air injection to surface water due to wake action and propeller use. Also, there were safety concerns with personnel (including divers) working in such a congested area. To reduce the potential for survey vessels to impact the measurements, limited visual observation passes were conducted within the 50-foot-diameter circle. Commercial and recreational vessel track data collected during the pilot study using the Maritime Mobile Service are included in Appendix Bii of the RI Report.

4.2.4.5 Sediment Temperature

Sediment temperature was measured at each sampling station. Sediment temperature sensors were placed within each sampling station at depths of 1, 2, 3, 4, 5, 7.5, and 10 feet below the mudline. Temperature data were recorded every 30 minutes for a month surrounding the duration of the 8-day pilot study.

Sediment temperature decreased with depth below the mudline, as well as in shallow sediment intervals, over the course of the month-long measurement period as follows:

- In Dutch Kills, the arithmetic average sediment temperatures decreased with depth from 20.4°C (1 foot) to 14.9°C (7.5 foot). Shallow interval temperatures decreased, and deeper interval temperatures increased during the month.

- In the Turning Basin, the arithmetic average sediment temperature decreased with depth from 21.0°C (1 foot) to 14.3°C (10 foot). Shallow interval temperatures decreased, and deeper interval temperatures increased during the month.

Sediment temperatures during the pilot study event were consistent with the averages over the month-long deployment period (see Figure D4-20).

4.2.5 Sediment, Porewater, and Surface Water Samples

Sediment, porewater, and surface water samples were collected from the two pilot study stations. Surface and subsurface sediment samples were visually characterized for sediment physical characteristics and visual observations of potential NAPL in accordance with procedures in SOP NC-20 – Sediment and Native Material Core Processing and analyzed for bulk sediment chemistry including PAHs, n-alkanes and isoprenoids, extractable petroleum hydrocarbons and total hydrocarbons, TOC, soot carbon, percent solids, oil and grease, biochemical oxygen demand, chemical oxygen demand, *Clostridium perfringens*, physical parameters, and carbon isotopes (fraction modern carbon, delta carbon-13 of total carbon, carbon-14 [14C] of total carbon, and radiocarbon age). Porewater samples were analyzed for anions, salinity, dissolved inorganic carbon, and delta carbon-13 of dissolved inorganic carbon. Surface water samples were analyzed for chemical oxygen demand, biochemical oxygen demand, total solids, and TOC. A detailed description of the sediment, porewater, and surface water sampling plans and methodologies is provided in the FS FP Work Plan and FSAP – Addendum No. 2 (Anchor QEA 2018), while the analytical results are summarized in Tables D4-5a through D4-5c.

5 EVALUATION OF GAS EBULLITION-FACILITATED TRANSPORT OF NAPL/CONTAMINANTS

This section integrates the results of the 2015 and 2016 FESs; the 2017 pilot study; and other RI investigations of sediment chemistry, organic material sources to the Study Area, surface water quality, sediment strength, surface water depth, and sediment NAPL characterization to provide an overall picture of the dynamics of gas ebullition in the Study Area. Conclusions drawn from the RI surveys and FS Part 1 pilot study program are subject to revision following analysis of the FS Part 2 quantitative ebullition sampling program results in the FS Gas Ebullition DER (Anchor QEA 2021).

5.1 Gas Ebullition Processes

As described in Section 2, gas ebullition includes the formation and migration of the gas bubbles through soft sediment. Additionally, in portions of the Study Area gas bubbles can interact with NAPL/contaminants present in the sediment and transport the NAPL/ contaminants to surface water. These processes and the factors that influence their probability are illustrated in Figure D5-1.

In Sections 5.1.1 and 5.1.2, gas bubble generation, gas bubble migration (gas ebullition), and NAPL/contaminant transport are evaluated based on the findings of the 2105 and 2016 FESs and the 2017 pilot study.

5.1.1 Gas Bubble Generation

Organic material inputs, including potential sources and distribution of surface and subsurface sediment organic material, have been extensively studied as part of the Remedial Investigation/Feasibility Study (RI/FS) investigations. Surface water and sediment temperature have also been investigated during RI/FS investigations, including sediment temperature measurements during the 2017 pilot study. Findings of those investigations relevant to gas ebullition are evaluated in Sections 5.1.1.1 and 5.1.1.2.

5.1.1.1 Organic Material Inputs

Organic material inputs to the Study Area surface and subsurface sediment include naturally occurring marine vegetation and organisms; discharges of organic-rich materials, including fecal material and other anthropogenic organic material from CSOs; and other organic contaminants from commercial and recreational vessels, shoreline seeps, and point source discharges. The deposition and spatial distribution of these organic materials (shown as TOC percentage) in Study Area sediments is presented in Figure D5-2. CSOs and other outfalls that discharge organic material to the Study Area are shown in Figure D5-3.

The 2017 pilot study included laboratory measurement of 14C abundance in gas and sediment samples to evaluate depths where methanogenesis may be occurring and potential sources of methanogenesis. The 14C gas sample results are presented in Table D4-4 and Figures D4-13 and D4-14. Figure D5-4 presents the sediment carbon isotope results.

Figures D5-5a through D5-5f show the maximum sediment TOC concentrations (both in the top 5 feet of the sediment and in the entire sediment column) and apparent gas ebullition observations. Figures D5-6a through D5-6f present sediment NAPL visual observations (both in the top 5 feet of the sediment and in the entire sediment column) overlaid with apparent gas ebullition observations. This comparison of organic material with portions of the Study Area where gas ebullition was observed indicates that the majority of apparent gas ebullition-related observations were in areas with the highest sediment TOC concentrations.

5.1.1.2 Effect of Temperature

Surface water measurements were collected during RI/FS surface water quality sampling, and surface water temperature is additionally recorded at The Battery. A comprehensive seasonal record of surface water temperatures during 1 year of surface water sampling is available for the Study Area (see Figure D4-16). However, The Battery surface water measurement station records continuous surface water temperatures that were used to characterize seasonal temperature trends and supplement the Study Area temperature measurements. The Battery site is located at the U.S. Coast Guard station at the southern tip of Manhattan, near the confluence of the Hudson and East rivers, 3.6 miles from the confluence of Newtown Creek and the East River (i.e., the nearest Study Area boundary).

The Study Area annual arithmetic average surface water temperature is 14.9°C, and The Battery annual arithmetic average is 14.7°C, with similar annual maximum and minimum values as well.

To further evaluate the temperature depth profile in sediment, sediment temperatures were measured near the two pilot study sampling stations (temperature profile measurement locations are shown in Figure D3-5, and temperature depth profiles are shown in Figure D4-20).

The sediment temperature depth profiles were recorded during the period of September through October 2017 and indicate sediment temperatures in the top 2 feet of sediment are closely correlated to surface water temperatures, decreasing as surface water cooled over the measurement period. The beginning of the sediment temperature measurement period in September overlaps with the latter portion of the August-through-September annual seasonal maximum surface water temperature. Even during these months of high surface water temperature, sediment temperatures 5 feet or more below the mudline were in the middle portion of the 10°C to 20°C range in which methanogenesis is expected to be less productive (i.e., methanogenesis is expected to be more productive above this range).

The 2015 and 2016 FESs and the 2017 pilot study were all performed near the time of seasonal maximum surface water temperatures. Therefore, the FS gas ebullition field program includes additional surface water and sediment temperature measurements throughout the year to provide more information regarding the effect of seasonal temperatures on methanogenesis.

5.1.2 Gas Ebullition

The factors that affect bubble formation and migration include sediment strength and hydrostatic pressure and are discussed in Sections 5.1.2.1 and 5.1.2.2.

5.1.2.1 Effect of Sediment Strength

Due to the role of sediment strength in gas bubble migration through sediment (see Section 2), sediment strength was measured during the FS geotechnical field program. Sediment strength was measured using 19 full flow penetrometer tests, 24 seismic cone penetrometer tests, and 3 cone penetrometer tests. Sediment strength testing was performed at 25 locations across the Study Area, including locations near the two 2017 pilot study stations. Sediment strength measurement stations are shown in Figure D5-7. The full results of the FS geotechnical program will be provided in a subsequent FS-related data summary report, but the results of the in situ penetration tests have been included in this appendix to inform the gas ebullition evaluation (see Attachment D-1).

Fractures in the sediment form at the tip of the gas bubble as methanogenesis increases the bubble's internal pressure, until the sediment eventually fractures (see Figure D5-1). This is followed by the bubble size increasing as the bubble moves into the fractured zone, and the corresponding stress on the sediment generated by the bubble decreases. This process repeats, with methanogenesis contributing to additional bubble pressure increases, until the sediment fractures again. If the combined bubble pressure and size are sufficient to create stress that overcomes sediment strength, the bubble migrates upward. The bubble can eventually reach the sediment/water interface and migrate into the surface water column.

Bubbles may preferentially follow tracks previously created by bubbles that have migrated through the sediment. In theory, bubbles may also follow preferential pathways formed by other processes (e.g., burrowing organisms). Bubble tracks may persist for days or up to months in some sediments (Scandella et al. 2017).

Greater sediment depths typically increase confining pressure (the combined pressure associated with the weight of the overlying sediment and the hydrostatic pressure over the overlying surface water column) on the sediment, with the lowest sediment strengths occurring at the sediment/water interface. The resultant increase in confining stress can effectively increase the sediment strength, thus limiting or prohibiting bubble formation, growth, or migration (see Figure D5-1). Study Area sediment strength testing results confirm this trend for Study Area sediment. Additionally, the increase in hydrostatic pressure alone can increase the solubility of dissolved gas in porewater, contributing to the limiting of bubble formation. The extent to which bubble formation, growth, and migration may be limited by depth in sediment will be further evaluated and discussed in the FS report.

Sediment strength measurements versus depth are shown in Attachment D-1.

5.1.2.2 Effect of Hydrostatic Pressure/Tidal Elevations

A plot of all gas ebullition observations versus water depth indicates gas ebullition was limited to water depths generally less than 6 meters deep (see Figure D5-8). Gas bubbles and sheen blossoms are compared to tidal elevations in Figures D5-9 and D5-10 to demonstrate that the increase in hydrostatic pressure associated with high tide also decreases bubble migration and sheen blossom formation. The daily window for gas ebullition activity is limited to approximately 2.5 hours prior to and 1.5 hours after low tide, with the maximum gas ebullition rate observed within a 1-hour window around low tide.

Additionally, fewer gas bubbles (and sheen blossoms) were observed during the 2017 pilot study compared to the 2016 FES observations for the Dutch Kills and Turning Basin sampling stations. The 2017 pilot study and 2016 FES were expected to have similar tidal elevations based on the tidal cycles at the time of the two surveys. Water temperatures were also expected to be similar for the two surveys, because they both occurred in September. If the tidal elevations and water temperatures were similar during the two surveys, then similar gas ebullition observations would be expected. However, gas bubble (and sheen blossom) spatial extent and frequency were both less during the 2017 pilot study than observed during the 2016 FES at the pilot study sampling station locations. The increase in surface water elevations above the predicted tidal elevations during the 2017 pilot study (associated with the storm surge from Hurricane Jose) and lower surface water temperatures were likely the cause for the decreased gas bubble (and sheen blossom) observations during that study.

5.2 NAPL/Contaminant Transport via Gas Ebullition

As discussed in Section 2, if gas ebullition occurs in areas with NAPL/contaminants in sediments at depths above the depth of gas bubble formation and migration, there is the potential for gas ebullition-facilitated NAPL/contaminant transport. Comprehensive RI/FS field investigations of the nature and extent of NAPL/contaminants have been and continue to be undertaken throughout the Study Area, as discussed in Appendix C of the RI Report. As shown in Figure D5-11, the largest areas of dynamic sheen observations are located in Dutch Kills, the Turning Basin, East Branch, and English Kills. These areas were the focus of the 2018/2019 FS gas ebullition field program.

Since expanding sheens do not appear to be transported via visible gas bubbles and they may not be associated with gas ebullition, the remainder of this discussion is focused on sheen blossom observations (regardless of the mechanism that causes sheen-bearing materials to rise to the water surface). As explained in Section 3.1.2.1, dynamic sheens include expanding sheens and sheen blossoms. Additional information regarding the transport process for expanding sheens was collected as part of the 2018/2019 FS gas ebullition field program, as wells as NAPL mobility analyses; these will be presented in a subsequent FS-related report.

The effect of temperature and water depth on gas ebullition-facilitated NAPL/contaminant transport are discussed in Section 5.2.1, and an evaluation of the potential correlation between gas ebullition-facilitated NAPL/contaminant transport and surface water chemistry is presented in Section 5.2.2.

5.2.1 Effect of Temperature and Water Depth on NAPL/Contaminant Transport

Similar to the discussion of the effect of temperature and water depth on gas bubble formation and migration in Section 5.1, the effect of temperature and water depth on gas ebullition-facilitated NAPL/contaminant transport is discussed in this section.

Since gas bubble growth and migration are the driving forces for gas ebullition-facilitated NAPL/contaminant transport, the effect of temperature and water depth on NAPL/contaminant transport is closely related to the effect on gas bubble growth and migration. Additionally, elevated sediment temperatures during warm weather in near surface sediment may decrease NAPL viscosity and allow the NAPL to be more readily mobilized by gas ebullition. As discussed in Section 5.1 for gas bubble growth and migration, the sediment temperature for given depth intervals changed by less than 2°C during the month-long measurement period. This is very likely less than the annual temperature range, particularly for shallow sediment, where temperature is correlated to surface water temperature. The annual temperature range for surface water exceeds 25°C. Therefore, the effect of temperature on Study Area NAPL/contaminant transport cannot be evaluated using these data. Additional sediment temperature data were collected during the 2018 full scale studies and in 2019.

A comparison of sheen blossom observations compared to water depth (see Figure D5-8) indicates minimal sheen blossom frequency in water depths greater than 6 meters. As discussed in Sections 5.1.2.1 and 5.1.2.2, increasing hydrostatic pressure from the increasing depth of the overlying surface water column suppresses gas ebullition. The relative increase in hydrostatic pressure associated with the relatively deeper water beyond the 6-meter depth is the likely reason for the observation of only minimal gas ebullition in areas with water deeper than 6 meters. Additionally, decreased solar heating of shallow sediment in deeper water may also result in lower temperatures and less gas ebullition (Zamanpour and Rockne 2018).

5.2.2 Effect of NAPL/Contaminant Transport on Surface Water Chemistry

Surface water chemistry measurements collected during RI investigations were compared to water depths/tidal elevations and surface water temperature to evaluate a potential correlation between gas ebullition-facilitated NAPL/contaminant transport and surface water chemistry. The 2015 and 2016 FES and 2017 pilot study observations indicate that gas ebullition-facilitated NAPL/contaminant transport is expected to increase with decreasing water depths/tidal elevation and increasing temperature. Therefore, surface water chemistry would be expected to show more significant impacts during seasonal higher temperatures and near the time of low tide, if NAPL/contaminant transport were a significant contaminant migration pathway to surface water. A total of 904 Study Area surface water samples were collected for laboratory chemical analyses during the period 2012 to 2015, at all times of the year and during all phases of the daily tidal cycle. The robust surface water chemistry dataset is expected to capture trends that may be associated with temperature and tidal fluctuations, if significant. However, surface water samples were collected below the water surface, so they likely did not capture sheens from gas ebullition that were in the process of spreading across the water surface before dissolving, partitioning onto solids, and/or potentially degrading, but the samples should represent conditions after such processes have occurred. Surface water sampling stations are shown in Figure D5-12.

As indicated in Figures D5-13a through Figure D5-13f, neither surface water temperature nor tidal elevation affect surface water chemistry. This finding supports that NAPL/contaminant transport is not a significant contaminant migration pathway from the perspective of influence on surface water chemistry.

Figures D5-13a and D5-13b compare total polycyclic aromatic hydrocarbon (17) (TPAH [17]) and TPH in surface water versus surface water temperature. These plots indicate there is no consistent correlation in the Study Area between the TPAH (17) and TPH and the increased gas ebullition observations with increased surface water temperature.

Figures D5-13c and D5-13d compare TPAH (17) and TPH concentrations in surface water versus the minimum tidal elevation 24 hours prior to sample collection, for the period of June through September (for the 2012 to 2015 period) when surface water temperatures are expected to be highest. This comparison would be expected to show higher surface water contaminant concentrations for lower tidal elevations, if gas ebullition-facilitated NAPL/contaminant transport significantly influenced surface water chemistry. Such a relationship between surface water chemistry and tidal elevation is not observed in the comparison, indicating that there is no correlation between the TPAH (17) and TPH and the tidal elevation for the period of June through September when surface water temperatures are expected to be highest.

Figures D5-13e and D5-13f compare TPAH (17) and TPH concentrations in surface water versus the minimum tidal elevation 24 hours prior to sample collection, for the period of October through May (for the 2012 to 2015 period) when surface water temperatures are expected to be lowest. This comparison would be expected to show higher surface water contaminant concentrations for lower tidal elevations if gas ebullition-facilitated NAPL/contaminant transport significantly influenced surface water chemistry. Such a relationship between surface water chemistry and tidal elevation is not observed in the comparison, indicating that there is no correlation between the TPAH (17) and TPH concentrations and the tidal elevation for the period of October through May when surface water temperatures are expected to be lowest.

6 SUMMARY OF THE GAS EBULLITION EVALUATION

Overall, the results of the FES and pilot study investigations provide a comprehensive evaluation of the spatial extent of potential sources for methanogenesis, the effect on the gas ebullition process of periodic changes in tidal elevation and seasonal surface water temperatures, and the interaction between gas ebullition and sediment NAPL/contaminants. The surveys discussed in this appendix covered a wide area (totaling approximately 140 acres and covering approximately 82% of the Study Area) and characterized a representative range of environmental conditions.

Scientifically rigorous gas ebullition FES and pilot study approaches were developed to accomplish the following: observation of gas bubbles and surface water sheens, measurement or observation of environmental conditions, and development and testing of equipment for measuring NAPL/contaminant and gas fluxes.

Two FESs were conducted, one in August 2015 and the other in September 2016. In addition, a pilot study to quantitatively measure NAPL and gas fluxes from gas ebullition was conducted in September 2017. The FESs and pilot study were conducted in mid-August and mid-September during a spring tide (lower tidal elevations) and peak seasonal water temperatures. Scientific literature cited throughout this appendix reports that gas ebullition is most productive at higher seasonal temperatures, due to increased activity among the microorganisms that generate gas in sediment; at lower tidal elevations, due to lower hydrostatic pressure; and in shallow water, due to more solar heating and relatively increased temperatures. Therefore, the gas ebullition studies were performed during the time of year when gas ebullition is expected to be most active and are likely a conservative record of observations of apparent gas ebullition, compared to other times of the year when temperatures are seasonally lower and tidal elevations are higher (i.e., non-spring tide conditions). In particular, the 2016 FES, which mapped the spatial extent of dynamic sheen and gas bubbles near peak seasonal temperatures coincident with spring tides, is expected to represent near maximum conditions. Due to the conditions under which this study was conducted and the area surveyed, it is considered representative of the near maximum extent of the portions of the Study Area where gas ebullition occurs (see Figure D4-2b).

The findings of the Gas Ebullition Evaluation can be summarized as follows:

- Surface water temperature (near annual maximum water temperatures and inferred corresponding sediment temperatures) and tidal elevations (spring tide) during the 2016 FES were near optimal conditions for annual maximum gas ebullition representing the 99.7 percentile with only two tides in 2016 having combined lower water elevations and higher water temperatures. Therefore, the spatial extent of gas bubble and sheen blossom observations documented in 2016 is expected to be near annual maximums (see Figure D6-1). While sediment temperatures were not available during the 2016 FES, the FS Part 2 program showed that sediment temperatures from 0 to 5 feet below mudline followed the trends of the overlying surface water (Anchor QEA 2021). Therefore, it is reasonable to infer that because near annual maximum surface water temperatures were measured during the 2016 FES, the sediment temperatures were optimal (i.e., near annual maximum temperatures) for annual maximum gas ebullition.
- Based on the RI field ebullition surveys, gas ebullition appears to be limited to areas with water depths shallower than 6 meters. The 2016 FES included observations in multiple areas with water depths greater than 6 meters, with no observations of sheen blossoms and minimal observation of gas bubbles (see Figure D5-8). More widespread gas bubbles were observed in the tributaries, where the water depths are generally shallower than the deeper water in the main stem (see Figures D4-4a and D4-4b).
- Sheen blossom and gas bubble observations during the 2015 and 2016 FESs and the 2017 pilot study differed throughout the Study Area. The differences in observations between the various survey/sampling areas are likely associated with differences in organic material content and quality, as well as the NAPL content in the sediment (see Figures D5-5a through D5-5f and D5-6a through D5-6f). Comparison of gas bubble observations and sediment TOC indicates the most significant apparent gas ebullition-related observations were generally in areas with the highest TOC concentrations. Other factors, including sediment strength and water depth, may also influence differences in the gas ebullition process.
- The majority of methanogenesis is expected in shallower sediments, where temperatures are warmest and sediment strengths are weakest.
- The occurrence of gas bubbles and sheen blossoms generally increases with lower tidal elevations.

- The daily window for gas ebullition activity is limited to approximately 2.5 hours prior to and 1.5 hours after low tide, with the maximum gas ebullition rate observed within a 1-hour window around low tide (see Figure D5-9).
- Comparisons of RI surface water chemistry measurements with water depths/tidal elevations and surface water temperature provide lines of evidence regarding the potential impact of gas ebullition on surface water contamination. Correlations were not found, indicating that neither surface water temperature nor tidal elevation affect surface water chemistry (see Figures D5-13a through D5-13f). Shallow surface water samples were collected 1 foot below the water surface, so they likely did not capture sheens from gas ebullition that were in the process of spreading across the water surface before dissolving, partitioning onto solids, and/or potentially degrading, but the samples should represent conditions after such processes have occurred. These results, combined with other lines of evidence presented in this report, lead to the conclusion that NAPL/contaminant transport by gas ebullition is not a significant contaminant migration pathway affecting surface water concentrations.
- Static sheens not related to sheen blossoms were observed in both 2015 and 2016. In particular, significant portions of the Study Area were covered by static sheen after precipitation was observed during the 2016 FES (see Figures D4-2a and D4-2b), which appeared, in part, to be related to point source discharges. On September 19, 2016, sheens were observed by NCG originating from three outfalls: NCB-683, NCQ-637, and BB-609 or BB-610 (as noted previously, while seemingly unlikely because the sheens tend to dissipate over time, because these outfalls are submerged at high tide, static sheen could have entered the outfall due to tidal movement prior to the observation of the sheens originating from these outfalls). Static sheens related to spills were also observed.
- The 2017 pilot study demonstrated the feasibility of quantitatively measuring NAPL/contaminant and gas flux, using near-bottom flux chambers.
- Visual observations of sheen blossoms and gas bubbles were generally consistent with gas ebullition-facilitated NAPL/contaminant flux and gas flux measurements during the pilot study. An attempt to better establish a relationship between visual observations and measured NAPL/contaminant flux was made during the 2018/2019 FS gas ebullition field program.

Additional investigation of gas ebullition-facilitated transport of NAPL/contaminants was initiated in July 2018 and continued with a visual survey event in 2019 and camera observations as part of the FS gas ebullition field program. The program includes additional NAPL/contaminant and gas flux measurements (July and October 2018), visual observations of sheens and gas bubbles (July 2018, October 2018, and January 2019 visual surveys and camera observations), sediment temperature depth profile measurements, and measurements/observations during different times of the year to capture the effect of different temperatures on gas ebullition-facilitated transport of NAPL/contaminants. Following this program, the results were used to extrapolate flux measurements to other times of the year and/or other areas of the Study Area for use in refinement of the RI/FS conceptual site model and to potentially support the development and technology screening of FS alternatives (Anchor QEA 2021).

7 REFERENCES[4]

Adriaens et al. (Adriaens, P., S.J. Wright, C.L. Gruden, J. Wolfe, T. Redder, N. Barabas, and J. DePinto), 2009. *Integrating Uncertainty Analysis in the Risk Characterization of In-Place Remedial Strategies for Contaminated Sediments*. Prepared for U.S. Department of Defense, Strategic Environmental Research and Development Program. March 2009.

Algar et al. (Algar, C.K., B.P. Boudreau, and M.A. Barry), 2011. Initial Rise of Bubbles in Cohesive Sediments by a Process of Viscoelastic Fracture. *Journal of Geophysical Research* 116(B4):1–14.

Anchor QEA (Anchor QEA, LLC), 2015. *Phase 2 Field Sampling and Analysis Plan – Volume 2 Addendum No. 3*. Remedial Investigation/Feasibility Study, Newtown Creek. August 2015.

Anchor QEA, 2016. *Phase 2 Field Sampling and Analysis Plan – Volume 2 Addendum No. 4.* Remedial Investigation/Feasibility Study, Newtown Creek. September 2016.

Anchor QEA, 2017. *Feasibility Study Field Program Work Plan*. Remedial Investigation/Feasibility Study, Newtown Creek. October 2017.

Anchor QEA, 2018. *Feasibility Study Field Program Work Plan and Field Sampling and Analysis Plan Addendum No. 2: Gas Ebullition Field Program*. Remedial Investigation/Feasibility Study, Newtown Creek. June 2018.

Anchor QEA, 2021. *Feasibility Study Gas Ebullition Data Evaluation Report*. Draft. Remedial Investigation/Feasibility Study, Newtown Creek. September 2021.

Blischke and Olsta (Blischke, H., and J. Olsta), 2009. *Long-term Investigation of Capping Remediation of Contaminated Sediment*. Paper presented at 29th Western Dredging Association Technical Conference, Tempe, Arizona. June 2009.

Boehme et al. (Boehme, S.E., N. Blair, J. Chanton, and C.S. Martens), 1996. A Mass Balance of 13C and 12C in an Organic-rich Methane-producing Marine Sediment. *Geochimica et Cosmochimica Acta* 60(20):3835–3848.

[4] ‡ denotes reference citations that are included in figures. References in tables are included as full references in the table notes.

Casper et al. (Casper, P., S. Maberly, G. Hall, and B. Finlay), 2000. Fluxes of Methane and Carbon Dioxide from a Small Productive Lake to the Atmosphere. *Biogeochemistry* 49:1-19.

Chapelle, F.H., 2001.‡ *Ground-water Microbiology and Geochemistry.* New York: John Wiley and Sons, Inc.

Chattopadhyay et al. (Chattopadhyay, S., V. Lal, and E. Foote), 2010. *Bench-Scale Evaluation of Gas Ebullition on the Release of Contaminants from Sediments*. Final Report. Prepared for U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/R-10/062. February 2010.

CSTAG (Contaminated Sediments Technical Advisory Group), 2015. Memorandum to Caroline Kwan (U.S. Environmental Protection Agency) from Stephen Ells (CSTAG). Regarding: CSTAG Recommendations on the Newtown Creek Contaminated Sediment Superfund Site. July 9, 2015.

Duan and Mao (Duan, Z., and S. Mao), 2006.‡ A Thermodynamic Model for Calculating Methane Solubility, Density and Gas Phase Composition of Methane-bearing Aqueous Fluids from 273 to 523K and from 1 to 2000 Bar. *Geochimica et Cosmochimica Acta* 70(13):3369 – 3386.

Emerson and Hedges (Emerson, S. and J. Hedges), 2003.‡ Sediment Diagenesis and Benthic Flux. Volume 6. In *Treatise on Geochemistry*, edited by Heinrich D. Holland and Karl K. Turekian. Elsevier Ltd., 293-319.

Fendinger et al. (Fendinger, N.J., D.D. Adams, and D.E. Glotfelty), 1992. The Role of Gas Ebullition in the Transport of Organic Contaminants from Sediment. *Science of the Total Environment* 112(2–3):189-201.

Fitzpatrick et al. (Fitzpatrick, F., M. Boufadel, R. Johnson, K. Lee, T. Graan, A. Bejarano, Z. Zhu, D. Waterman, D. Capone, E. Hayter, S. Hamilton, T. Dekker, M. Garcia, and J. Hassan), 2015. *Oil-Particle Interactions and Submergence from Crude Oil Spills in Marine and Freshwater Environments—Review of the Science and Future Science Needs*. Prepared for the U.S. Geological Survey. June 2015.

Huttunen et al. (Huttunen, J., K. Lappalainen, E. Saarijärvi, T. Väisänen, and P. Martikainen), 2001. A Novel Sediment Gas Sampler and a Subsurface Gas Collector Used for

Measurement of the Ebullition of Methane and Carbon Dioxide from a Eutrophied Lake. *The Science of the Total Environment* 266:153-158.

Joyce and Jewell (Joyce, J., and P. Jewell), 2003. Physical Controls on Methane Ebullition from Reservoirs and Lakes. *Environmental and Engineering Geoscience* 9(2):167-178.

Lay et al. (Lay, J., T. Miyahara, and T. Noike), 1996. Methane Release Rate and Methanogenic Bacterial Populations in Lake Sediments. *Water Research* 30(4):901-908.

McLinn and Stolzenburg (McLinn, E.L., and T.R. Stolzenburg), 2009. Ebullition-facilitated Transport of Manufactured Gas Plant Tar from Contaminated Sediment. *Environmental Toxicology and Chemistry* 28(11):2298–2306.

Poissant et al. (Poissant, L., P. Constant, M. Pilote, J. Canário, N. O'Driscoll, J. Ridal, and D. Lean), 2007. The Ebullition of Hydrogen, Carbon Monoxide, Methane, Carbon Dioxide and Total Gaseous Mercury from the Cornwall Area of Concern. *Science of the Total Environment* 381:256-262.

Rockne et al. (Rockne, K.J., P.Z. Viana, and K. Yin), 2010. *Sediment Gas Ebullition and Flux Studies, Bubbly Creek, South Fork South Branch, Chicago River, Volume 1 of 2: Report with Appendices A-D.* Prepared for U.S. Army Corps of Engineers. July 2010.

Salminen et al. (Salminen, J.M., P.J. Hanninen, J. Leveinen, P.T.J. Lintenen, and K.S. Jorgensen), 2006.‡ Occurrence and Rates of Terminal Electron-Accepting Processes and Recharge Processes in Petroleum Hydrocarbon-Contaminated Subsurface. *Journal of Environmental Quality* 35:2273-2282.

Scandella et al. (Scandella, B., K. Delwiche, H. Hemond, and R. Juanes), 2017. Persistence of Bubble Outlets in Soft, Methane-Generating Sediments. *Journal of Geophysical Research: Biogeosciences* 122:1298-1320.

Schmidt, M., 2016. Regarding: Newtown Creek – FS Field Investigation Approach. E-mail to: Jim Quadrini. October 26, 2016.

Sittoni et al. (Sittoni, L., W. van Kesteren, K. Kuijper, T. van Kessel, and A. Wijdeveld), 2015. *Application of a Gas Ebullition and Consolidation Model for Determining the Thickness of a Sand Cap That Eliminates Gas Emission*. Presentation at Battelle Eighth International Conference on Remediation and Management of Contaminated Sediments, New Orleans, Louisiana. January 2015.

USEPA (U.S. Environmental Protection Agency), 2016. *Newtown Creek RI/FS: FS Field Investigation Approach*. October 26, 2016.

Viana et al. (Viana, P., K. Yin, X. Zhao, and K. Rockne), 2007. Active Sediment Capping for Pollutant Mixtures: Control of Biogenic Gas Production under Highly Intermittent Flows. *Land Contamination and Reclamation* 15(4):413-425.

Viana et al. (Viana, P., K. Rockne, and L. Thai), 2011. *Sediment Gas Ebullition and Flux Studies in Bubbly Creek, South Fork South Branch, Chicago River*. Presentation, Sixth International Conference on Remediation of Contaminated Sediments, Louisiana, New Orleans. February 2011.

Viana et al. (Viana, P., K. Yin, and K. Rockne), 2012. Field Measurements and Modeling of Ebullition-facilitated Flux of Heavy Metals and Polycyclic Aromatic Hydrocarbons from Sediments to the Water Column. *Environmental Science and Technology* 46(21):12046-54.

Viana et al. (Viana, P., M. Gefell, M. Gravelding, M. Hanish, and K. Paschl), 2015. *Understanding and Addressing Ebullition-facilitated Sheening in Cap Design*. Presentation at Battelle Eighth International Conference on Remediation and Management of Contaminated Sediments, New Orleans, Louisiana. January 2015.

Yin et al. (Yin, K., P. Viana, X. Zhao, and K. Rockne), 2010. Characterization, Performance Modeling, and Design of an Active Capping Remediation Project in a Heavily Polluted Urban Channel. *Science of the Total Environment* 408(16):3545-3463.

Zamanpour and Rockne (Zamanpour, M.K. and K.J. Rockne), 2018. *A Mechanistic Model for Gas Ebullition in the Presence of NAPL in Sediments*. World Environmental and Water Resources Congress. American Society of Civil Engineers. May 31, 2018.

Zeikus, J., and M. Winfrey, 1976. Temperature Limitation of Methanogenesis in Aquatic Sediments. *Applied and Environmental Microbiology* 31(1):99-107.

TABLES

Table D3-1
Survey Dates and Environmental Conditions

Gas Ebullition Field Survey		Survey Date	Tidal Elevation (feet MLLW)	Tidal Difference (feet)	Average Water Temperature (degrees Celsius)
2015	High Tide Survey No. 1	08/18/2015	4.2	NA	24.7
	Low Tide Survey No. 1	08/18/2015	0.7	3.6	25.1
	Low Tide Survey No. 2	08/19/2015	0.5	3.6	25.1
2016	Low Tide Survey No. 1	09/16/2016	-0.2	5.1	24.5
	Low Tide Survey No. 2	09/17/2016	-0.4	5.5	24.2
	Low Tide Survey No. 3	09/18/2016	-0.4	5.6	24.0
	Low Tide Survey No. 4	09/19/2016	-0.3	5.6	23.9
2017	Low Tide Survey No. 1	09/18/2017	0.5	5.2	22.2
	Low Tide Survey No. 3	09/20/2017	0.8	5.8	22.4
	Low Tide Survey No. 4	09/21/2017	0.8	5.2	22.4

Note:
Tidal data from 2015 and 2016 were obtained from the National Oceanic and Atmospheric Administration for Hunter's Point, Newtown Creek, New York; 2017 tidal data were obtained from the Turning Basin tidal gauge.

Acronyms:
MLLW = mean lower low water
NA = not available

Table D3-2
Range of Environmental Conditions Surveyed

Gas Ebullition Survey or Pilot Study Area	2015 Survey Area	2016 Survey Area	2017 Pilot Study Area	Environmental Conditions in Area
Main stem: CM 0.19 to 0.5	X			• Water depth ranges to 20-plus feet MLLW • NAPL Category 1B Area, shallowest NAPL observed at 75 cm below mudline
Main stem: CM 0.67 to 0.83	X			• Frequent vessel traffic • Water depth ranges to 20-plus feet MLLW • NAPL Category 1B Area, shallowest NAPL observed at 30 cm below mudline
Main stem: CM 0.9 to 1.36	X			• Depositional/hydrodynamic conditions differ from CM 0 to 0.5 • Water depth ranges to 20-plus feet MLLW • NAPL Category 1B Area, shallowest NAPL observed at 85 cm below mudline
Main stem: CM 1.6 to 1.94	X			• NAPL Category 1B Area and CM 1.7 NAPL Category 2/3 Area, shallowest NAPL observed at 35 cm below mudline
Main stem: CM 0.57 to 1.94		X		• Frequent vessel traffic • Water depth ranges to 20-plus feet MLLW • NAPL Category 1B Area and CM 1.7 NAPL Category 2/3 Area, shallowest NAPL observed at 30 cm below mudline
Dutch Kills	X	X	X	• High organic carbon • Bridge obstruction limits access to approximately 2 to 3 hours before and after low tide • NAPL Category 1A Area (NAPL not observed)
Turning Basin	X	X	X	• Frequent vessel traffic • High organic carbon • Aeration system installed in 2018 • Water depth ranges from 20-plus feet to less than 5 feet MLLW • NAPL Category 1B Area and Turning Basin NAPL Category 2/3 Area, shallowest NAPL observed at mudline
Maspeth Creek	X	X		• High organic carbon • Water depth ranges from 20-plus feet to less than 5 feet MLLW • NAPL Category 1B Area, shallowest NAPL observed at 33 cm below mudline
East Branch	X	X		• High organic carbon • Aeration system installed in 2018 • NAPL Category 1B Area, shallowest NAPL observed at 10 cm below mudline
English Kills	X	X		• High organic carbon • Aeration system • NAPL Category 1B Area and lower English Kills NAPL Category 2/3 Area, shallowest NAPL observed at mudline

Note:
Shallowest NAPL depths refer to the depth closest to the mudline with blebs, coated, or saturated visual observations in the sediment.

Acronyms:
cm = centimeter
CM = creek mile
MLLW= mean lower low water
NAPL = nonaqueous phase liquid

Table D3-3
Sheen and Gas Bubble Observation Terminology

Sheen Distribution Terminology		
Type	**Term**	**Description**
Dynamic	Blossom	Observations of a sheen area developing when a gas bubble breaks on the water surface
	Expanding	Observations of a sheen area developing on the water surface in the absence of a visible gas bubble
Static	Small Spots	Isolated patches (less than 3 feet in diameter) of sheen (describe size and number)
	Spotty	Larger areas of sheen that comprise many smaller patches (less than 3 feet in diameter) of sheen that may merge or separate over time (describe size and number)
	Streaks	Flat lines of sheen (describe size, number, and orientation)
	Contiguous	A larger patch of sheen (greater than 3 feet in diameter) (describe size)
Sheen Structure Terminology		
Term	**Description**	
Brittle	Sheen cracks and breaks apart when disturbed	
Non-brittle	Sheen coalesces after being disturbed	
Sheen Color Terminology (Modified from ASTM F2534-06)		
Color	**Description**	
Silvery	Metallic, near transparent to silver/gray	
Rainbow	Multicolored	
Dark Rainbow	Multicolored with some dark metallic or brown/black	
Dark	Dark metallic (reflects/mirrors the color of the sky) or brown/black	
Gas Bubble Frequency		
Frequency	**Description**	
Moderate-high frequency	Bubbles are observed continuously or nearly continuously with regard to time, within the area apparent gas ebullition is observed. Areas with gas ebullition frequencies more than 100 bubbles per minute were assigned to this category.	
Low-moderate frequency	Bubbles appear intermittently or irregularly with regard to time, within the area apparent gas ebullition is observed. Areas with gas ebullition frequencies of more than 10 but less than 100 bubbles per minute were assigned to this category.	
Trace-low frequency	Bubbles appear but less frequently than low-moderate with regard to time, within the area apparent gas ebullition is observed. Areas with gas ebullition frequencies up to 10 bubbles per minute were assigned to this category.	
Gas Bubble Spatial Distribution		
Distribution	**Description**	
Moderate-high distribution	Bubbles are widespread within the area apparent gas ebullition is observed.	
Low-moderate distribution	Bubbles appear intermittently or irregularly within the area where apparent gas ebullition is observed.	
Trace-low distribution	Bubbles occur only at specific, localized points within the area where apparent gas ebullition is observed.	

Acronym:
ASTM = ASTM International

Table D4-1
Summary of Sheen and Apparent Gas Bubble Observations

Gas Ebullition Survey Area	Number of Dynamic Sheen Observations[1]				Number of Static Sheen Observations[1]		Number of Gas Bubble Observations[1,2]	
	Sheen Blossoms		Expanding Sheen					
	2015	2016	2015	2016	2015	2016	2015	2016
Main stem: CM 0.19 to 0.5	0	NA	0	NA	1	NA	0	NA
Main stem: CM 0.57 to 0.93	NA	2	NA	0	NA	5	NA	38
Main stem: CM 0.67 to 0.83	0	NA	0	NA	1	NA	0	NA
Main stem: CM 0.9 to 1.36	0	NA	0	NA	4	NA	3	NA
Main stem: CM 0.93 to 1.43	NA	2	NA	0	NA	37	NA	31
Main stem: CM 1.43 to 1.94	NA	4	NA	3	NA	55	NA	52
Main stem: CM 1.6 to 1.94	0	NA	0	NA	4	NA	2	NA
Dutch Kills	0	36	0	1	11	135	10	162
Turning Basin	3	56	0	1	8	143	8	112
Maspeth Creek	0	2	0	0	0	15	5	36
East Branch	0	50	0	1	7	78	7	122
English Kills	1	88	0	13	11	166	10	327
Whale Creek	NA	7	NA	3	NA	12	NA	44

Notes:
1 = Observations of sheen and gas bubbles include both individual point observations (e.g., one sheen blossom) and observations within subareas, shown as polygons in figures, where observations were consistent (e.g., same gas bubble rate) and the extent of the area with consistent observations was mapped.
2 = Includes all observations of gas bubbles regardless of source.

Acronyms:
CM = creek mile
NA = not applicable

Table D4-2
Flux Chamber Sample Collection Summary

Station ID	Sampling Method	Sample Frequency	Sample ID	NAPL/Contaminant Testing: Oil and Grease, PAHs and Alkyl PAHs, N-alkanes and Isoprenoids, and EPH	Gas Testing[3]: Gas Identification, Carbon-14 of Carbon Dioxide, and Carbon-14 of Methane
DK052	NAPL/contaminant flux – glass wool	3-day period[1]	DK052WL-A-20170921	X	
			DK052WL-C-20170921		
			DK052WL-D-20170921		
	Gas flux chamber		DK052GF-A-20170921		X
			DK052GF-C-20170921		
			DK052GF-D-20170921		
NC342	NAPL/contaminant flux – glass wool	4-day period[2]	NC342WL-A-20170922	X	
			NC342WL-B-20170922		
			NC342WL-C-20170922		
			NC342WL-D-20170922		
			NC342WL-E-20170922		
	Gas flux chamber		NC342GF-A-20170922		X
			NC342GF-B-20170922		
			NC342GF-C-20170922		
			NC342GF-D-20170922		
			NC342GF-E-20170922		

Notes:
1 = Flux chambers were deployed for 4 days, but a weather stand-down day and limited access reduced sampling to 3 days. See FS Deviation Memorandum No. 2, Field Deviation Form 2-6 for more details.
2 = Flux chambers were deployed for 5 days, but sampling occurred on 4 days due to a weather stand-down day. See FS Deviation Memorandum No. 2, Field Deviation Form 2-6 for more details.
3 = Gas identification includes methane, carbon dioxide, carbon monoxide, oxygen, nitrogen, hydrogen, helium, hydrogen sulfide, argon, and carbon (C1 to C6).

Acronyms:
EPH = extractable petroleum hydrocarbon
FS = Feasibility Study
NAPL = nonaqueous phase liquid
PAH = polycyclic aromatic hydrocarbon

Table D4-3
Flux Chamber Contaminant Flux Results Summary

Sample ID[1]	Chemical Type[2]	Chamber Chemical Mass (mg)[3]	Control Chemical Mass (mg)[3]	Corrected Chemical Mass (mg)[4]	Days Deployed	Corrected Chemical Weight per Sampling Area per Day (mg/m²/day)[5]	Average Corrected Chemical Flux per Day (mg/m²/day)
DK052WL-A-20170921	Total PAH	0.00	0.00	0.00	3	0.00	0.00
DK052WL-C-20170921		0.00	0.00	0.00	3	0.00	
DK052WL-D-20170921		0.00	0.00	0.00	3	0.00	
NC342WL-A-20170922		0.21	0.00	0.21	4	0.15	0.04
NC342WL-B-20170922		0.02	0.00	0.02	4	0.01	
NC342WL-C-20170922		0.05	0.00	0.04	4	0.03	
NC342WL-D-20170922		0.01	0.00	0.01	4	0.00	
NC342WL-E-20170922		0.01	0.00	0.01	4	0.01	
DK052WL-A-20170921	Total EPH[6]	0.00	0.00	0.00	3	0.00	0.00
DK052WL-C-20170921		0.46	0.00	0.46	3	0.45	
DK052WL-D-20170921		0.00	0.00	0.00	3	0.00	
NC342WL-A-20170922		0.56	0.00	0.56	4	0.41	0.62
NC342WL-B-20170922		0.87	0.00	0.87	4	0.64	
NC342WL-C-20170922		0.79	0.00	0.79	4	0.58	
NC342WL-D-20170922		0.00	0.56	-0.56	4		
NC342WL-E-20170922		1.18	0.00	1.18	4	0.86	
DK052WL-A-20170921	TPH	0.51	0.14	0.37	3	0.36	0.29
DK052WL-C-20170921		2.15	0.00	2.15	3	2.11	
DK052WL-D-20170921		0.64	0.42	0.22	3	0.22	
NC342WL-A-20170922		6.12	0.30	5.82	4	4.28	1.76
NC342WL-B-20170922		1.04	0.31	0.73	4	0.54	
NC342WL-C-20170922		1.91	0.54	1.38	4	1.01	
NC342WL-D-20170922		0.75	0.82	-0.07	4		
NC342WL-E-20170922		1.78	0.14	1.64	4	1.20	
DK052WL-A-20170921	Oil and grease	0.00	0.00	0.00	3	0.00	0.00
DK052WL-C-20170921		6.60	0.00	6.60	3	6.47	
DK052WL-D-20170921		0.00	0.00	0.00	3	0.00	
NC342WL-A-20170922		0.00	0.00	0.00	4	0.00	1.06
NC342WL-B-20170922		0.00	0.00	0.00	4	0.00	
NC342WL-C-20170922		7.20	0.00	7.20	4	5.29	
NC342WL-D-20170922		0.00	0.00	0.00	4	0.00	
NC342WL-E-20170922		0.00	0.00	0.00	4	0.00	
DK052WL-A-20170921	DRO	0.37	0.33	0.05	3	0.04	0.16
DK052WL-C-20170921		1.43	0.19	1.25	3	1.22	
DK052WL-D-20170921		0.58	0.29	0.28	3	0.28	
NC342WL-A-20170922		4.14	0.50	3.64	4	2.68	0.96
NC342WL-B-20170922		0.82	0.26	0.56	4	0.41	
NC342WL-C-20170922		1.37	0.10	1.27	4	0.93	
NC342WL-D-20170922		0.46	0.18	0.27	4	0.20	
NC342WL-E-20170922		0.98	0.20	0.78	4	0.57	

Notes:

1. The sampler associated with DK052WL-C on 9/21/2017 was inadvertently moved approximately 15 feet during a daily check, and data validity is, therefore, questionable. It was not included in the Dutch Kills flux chamber average.
2. Additional results for n-alkanes and isoprenoids are included in the FS DSR Part 1 (Appendix Bii of the RI Report).
3. Chemical mass is calculated by multiplying sample weight by three to be representative of three glass wool aliquots for both flux chambers and control samples. Nondetected results set to zero.
4. Corrected mass is calculated by subtracting the control mass from chamber mass (after multiplying each by three, per note 3). Chambers with mass greater in the control sampler than in the flux chamber not included in the average. Not including these results will positively bias the average flux. Setting these results to zero and including in the average could lead to not including NAPL mass that was captured by flux chamber because NAPL moving laterally into control sampler resulted in increased NAPL mass captured not related to gas ebullition.
5. Weight per sampling area per day is calculated by dividing corrected NAPL weight by internal area of the flux chamber (0.34 m²), dividing by the number of days the flux chamber was deployed.
6. Total EPH is the total extractable petroleum hydrocarbons as reported by the laboratory.

Acronyms:

DRO = diesel range organics
EPH = extractable petroleum hydrocarbon
FS DSR Part 1 = *Feasibility Study Data Summary Report Part 1*
m² = square meter
mg = milligram
mg/m²/day = milligrams per square meter per day
NAPL = nonaqueous phase liquid
PAH = polycyclic aromatic hydrocarbon
RI Report = *Remedial Investigation Report*
TPH = total petroleum hydrocarbon

Table D4-4
Gas Flux Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
Gas Flux ($L/m^2/day$)						
Gas Flux	8	8	100	0.040	2.1	0.47
Conventional Parameters (mol-pct)						
Carbon monoxide	8	0	0	--	--	--
Argon	8	8	100	0.19	0.9	0.6
Carbon dioxide	8	8	100	0.064	3.5	0.85
Ethane	8	5	63	0.0001	0.0007	0.00032
Ethene	8	0	0	--	--	--
Helium	8	1	13	0.0053	0.0053	0.0053
Hydrogen	8	6	75	0.018	1.1	0.4
Methane	8	8	100	11	81	42
Nitrogen, elemental	8	8	100	13	70	45
Oxygen	8	8	100	2.3	18	11
Conventional Parameters ($\mu g/m^3$)						
Hydrogen sulfide	8	3	38	20,000 J	75,000 J	46,000
Volatile Organics (mol-pct)						
2-Methyl butane (isopentane)	8	0	0	--	--	--
Butane	8	0	0	--	--	--
Isobutane	8	0	0	--	--	--
Propane	8	2	25	0.0001	0.0002	0.00015
Propylene (Propene)	8	0	0	--	--	--
n-Alkanes and Isoprenoids (mol-pct)						
Hexane (C6) and longer carbon chains	8	0	0	--	--	--
n-Pentane (C5)	8	0	0	--	--	--
Isotope Ratios (per mil VPDB)						
d13C of carbon dioxide[1]	3	3	100	-11	-1	-6.2
d13C of methane	8	8	100	-61	-54	-57
Isotope Ratios (pMC)						
Carbon-14 of carbon dioxide[1]	3	3	100	86	96	92
Carbon-14 of methane	8	8	100	95	99	97

Notes:
1 = insufficient carbon dioxide for analysis in five of eight samples
-- = indicates no information that is appropriate or available
J = estimated value
Percent detected results are rounded to the nearest whole number. Minimum, maximum, and average results are rounded to two significant figures, except where trailing zeros are not shown, resulting in one significant figure. Qualifiers are not shown on average results.

Acronyms:
$\mu g/m^3$ = micrograms per cubic meter
$L/m^2/day$ = liters per square meters per day
mol-pct = molar percent
per mil VPDB = parts per thousand Vienna Pee Dee Belemnite
pMC = percent modern carbon

Table D4-5a
Gas Ebullition Sediment Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
Conventional Parameters (mg/kg)						
Biochemical oxygen demand – 5 day (BOD5)	20	20	100	460	68,000 J	18,000
Chemical oxygen demand	20	20	100	24,000	2,000,000 J	430,000
Conventional Parameters (wt%)						
Moisture (water) content	20	20	100	85	420	240
Soot carbon	20	20	100	0.068	4 J	0.77
Total organic carbon	20	20	100	7.3	25	14
Total solids[1]	34	34	100	5.7	61	33
Conventional Parameters (lb/ft^3)						
Density (bulk)	20	20	100	66	85	74
Density (dry)	20	20	100	13	46	24
Conventional Parameters (unitless)						
Specific gravity	20	20	100	1.1	2.4	2.1
Pathogens (CFU/g)						
Clostridium perfringens	20	20	100	50,000	600,000	230,000
Polycyclic Aromatic Hydrocarbons (µg/kg)						
1-Methyldibenzothiophene	20	20	100	40 J	12,000	2,200
1-Methylnaphthalene	20	20	100	190	250,000	40,000
1-Methylphenanthrene	20	20	100	410	90,000	16,000
2,3,5-Trimethylnaphthalene (1,6,7-Trimethylnaphthalene)	20	20	100	130	51,000	9,300
2,6-Dimethylnaphthalene	20	20	100	420	260,000	42,000
2-Methylanthracene	20	20	100	150	33,000	6,900
2-Methyldibenzothiophene & 3-Methyldibenzothiophene	20	18	90	75 J	60,000	10,000
2-Methylnaphthalene	20	20	100	230	400,000	64,000
2-Methylphenanthrene	20	20	100	480	160,000	23,000
4-Methyldibenzothiophene	20	20	100	110	65,000	9,900
4-Methylphenanthrene & 9-Methylphenanthrene	20	20	100	390	100,000	18,000
Acenaphthene	20	20	100	460	110,000	23,000
Acenaphthylene	20	20	100	190	25,000	5,600
Anthracene	20	20	100	1,000	96,000	19,000
Benzo(a)anthracene	20	20	100	2,700	62,000	18,000
Benzo(a)pyrene	20	20	100	3,000	64,000	19,000
Benzo(b)fluoranthene	20	20	100	3,500	29,000	11,000
Benzo(e)pyrene	20	20	100	2,600	34,000	12,000
Benzo(g,h,i)perylene	20	20	100	2,400	29,000	10,000
Benzo(j,k)fluoranthene	20	20	100	2,800	30,000	12,000
Benzothiophene	20	18	90	25 J	27,000	3,900
Biphenyl (1,1'-Biphenyl)	20	20	100	98	37,000	7,000
Carbazole	20	20	100	260	4,000	1,300
Chrysene	20	20	100	3,900	60,000	19,000
Decalin, cis- & trans-	20	20	100	200 J	40,000	9,400
Dibenzo(a,h)anthracene and Dibenzo(a,c)anthracene	20	20	100	540	8,100	2,900
Dibenzothiophene	20	20	100	300	50,000	8,600
Fluoranthene	20	20	100	7,400	110,000	32,000
Fluorene	20	20	100	560	71,000	14,000

Table D4-5a
Gas Ebullition Sediment Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
Indeno(1,2,3-c,d)pyrene	20	20	100	2,000	22,000	8,500
Naphthalene	20	20	100	360	950,000	130,000
Naphthobenzothiophene	20	20	100	960	30,000	7,500
Perylene	20	20	100	810	10,000	3,700
Phenanthrene	20	20	100	4,500	310,000	61,000
Pyrene	20	20	100	5,700	170,000	45,000
Retene	20	11	55	930 J	120,000	29,000
Alkylated Polycyclic Aromatic Hydrocarbons (µg/kg)						
C1-Benzanthracenes/Chrysenes	20	20	100	1,800	84,000	23,000
C1-Benzo(b)thiophene	20	20	100	240	24,000	4,000
C1-Decalins	20	20	100	1,000	77,000	18,000
C1-Dibenzothiophenes	20	20	100	200	150,000	23,000
C1-Fluoranthenes/Pyrenes	20	20	100	2,600	180,000	43,000
C1-Fluorenes	20	20	100	270	110,000	17,000
C1-Naphthalenes	20	20	100	280	420,000	67,000
C1-Phenanthrenes/Anthracenes	20	20	100	1,800	490,000	83,000
C2-Benzanthracenes/Chrysenes	20	20	100	1,500	76,000	20,000
C2-Benzo(b)thiophene	20	20	100	71 J	32,000	5,000
C2-Decalins	20	20	100	1,400	91,000	21,000
C2-Dibenzothiophenes	20	20	100	490	190,000	31,000
C2-Fluorenes	20	20	100	750	200,000	33,000
C2-Naphthalenes	20	20	100	780	470,000	77,000
C2-Phenanthrenes/Anthracenes	20	20	100	1,800	410,000	73,000
C3-Benzanthracenes/Chrysenes	20	20	100	1,700	55,000	15,000
C3-Benzo(b)thiophene	20	20	100	150	42,000	6,500
C3-Decalins	20	20	100	630	75,000	16,000
C3-Dibenzothiophenes	20	20	100	600	120,000	21,000
C3-Fluorenes	20	20	100	1,900 J	160,000	29,000
C3-Naphthalenes	20	20	100	950	460,000	73,000
C3-Phenanthrenes/Anthracenes	20	20	100	1,300	190,000	37,000
C4-Benzanthracenes/Chrysenes	20	20	100	1,200	27,000	7,600
C4-Benzo(b)thiophene	20	20	100	120	35,000	5,400
C4-Decalins	20	20	100	670	120,000	24,000
C4-Dibenzothiophenes	20	20	100	460	49,000	9,700
C4-Naphthalenes	20	20	100	850	290,000	49,000
C4-Phenanthrenes/Anthracenes	20	20	100	850	77,000	19,000
n-Alkanes and Isoprenoids (µg/kg)						
2,6,10-Trimethyldodecane	20	20	100	1,300 J	240,000	51,000
2,6,10-Trimethyltridecane	20	20	100	2,400 J	420,000	85,000
n-Decane (C10)	20	9	45	1,500 J	46,000	11,000
n-Docosane (C22)	20	16	80	1,300 J	77,000	24,000
n-Dodecane (C12)	20	17	85	1,400 J	290,000	34,000
n-Dotriacontane (C32)	20	14	70	1,700 J	23,000	7,500
n-Eicosane (C20)	20	16	80	1,300 J	190,000	31,000
n-Heneicosane (C21)	20	9	45	1,100 J	91,000	22,000

Table D4-5a
Gas Ebullition Sediment Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
n-Hentriacontane (C31)	20	20	100	4,300	53,000	21,000
n-Heptacosane (C27)	20	17	85	2,300 J	45,000	13,000
n-Heptadecane (C17)	20	11	55	1,800 J	240,000	52,000
n-Heptatriacontane (C37)	20	11	55	2,600 J	14,000 J	6,600
n-Hexacosane (C26)	20	11	55	4,000 J	71,000	23,000
n-Hexadecane (C16)	20	18	90	1,600 J	300,000	40,000
n-Hexatriacontane (C36)	20	15	75	2,500 J	25,000	11,000
n-Nonacosane (C29)	20	14	70	6,800 J	44,000	20,000
n-Nonadecane (C19)	20	16	80	1,700 J	230,000	31,000
n-Nonane (C9)	20	1	5	14,000 J	14,000 J	14,000
n-Nonatriacontane (C39)	20	8	40	2,100 J	9,600 J	4,200
n-Octacosane (C28)	20	9	45	2,000 J	14,000 J	6,600
n-Octadecane (C18)	20	20	100	5,900 J	580,000	94,000
n-Octatriacontane (C38)	20	12	60	1,800 J	15,000 J	5,800
n-Pentacosane (C25)	20	20	100	12,000	130,000	49,000
n-Pentadecane (C15)	20	20	100	2,800 J	260,000	39,000
n-Pentatriacontane (C35)	20	19	95	3,500 J	37,000	13,000
n-Tetracontane (C40)	20	8	40	2,800 J	8,400 J	4,400
n-Tetracosane (C24)	20	8	40	2,300 J	20,000 J	9,000
n-Tetradecane (C14)	20	18	90	940 J	290,000	40,000
n-Tetratriacontane (C34)	20	18	90	3,000 J	33,000	12,000
n-Triacontane (C30)	20	12	60	4,000 J	25,000	12,000
n-Tricosane (C23)	20	11	55	1,200 J	66,000	21,000
n-Tridecane (C13)	20	17	85	1,300 J	390,000	48,000
n-Tritriacontane (C33)	20	17	85	6,300	110,000	27,000
n-Undecane (C11)	20	18	90	2,800 J	180,000	24,000
Norpristane	20	20	100	3,000 J	370,000	74,000
Phytane	20	20	100	7,800	420,000	91,000
Pristane	20	20	100	5,500	750,000	140,000
Extractable Petroleum Hydrocarbons (mg/kg)						
C9-C18 Aliphatics unadjusted	20	20	100	57	2,100	780
C19-C36 Aliphatics unadjusted	20	20	100	230	4,700 J	2,000
C11-C22 Aromatics adjusted	20	20	100	150	3,500 J	1,200
C11-C22 Aromatics unadjusted	20	20	100	150 J	3,500 J	1,200
Volatile Petroleum Hydrocarbons (mg/kg)						
C5-C8 Aliphatics adjusted	20	13	65	39 J	1,600 J	310
C5-C8 Aliphatics unadjusted	20	13	65	39 J	1,600 J	310
C9-C12 Aliphatics adjusted	20	16	80	81 J	2,200 J	660
C9-C12 Aliphatics unadjusted	20	19	95	62	4,300 J	1,200
C9-C10 Aromatics unadjusted	20	17	85	41	2,000 J	640
Total Petroleum Hydrocarbons (mg/kg)						
Oil and grease (HEM)	20	20	100	27,000	130,000	67,000
Diesel range organics (C10-C28)	20	20	100	4,300	91,000	26,000
Total petroleum hydrocarbons (C9-C40)	20	20	100	8,900	120,000	39,000

Table D4-5a
Gas Ebullition Sediment Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
Isotope Ratios (none)						
Fraction Modern Carbon (fMDN)	20	20	100	0.29	0.79	0.45
Isotope Ratios (per mil HOx2)						
D14C (Normalized value of d14C)	20	20	100	-710	-210	-550
Isotope Ratios (per mil VPDB)						
D13C of total carbon	20	20	100	-26	-21	-24
Isotope Ratios (pMC)						
Carbon-14 of total carbon	20	20	100	29	79	45
Isotope Ratios (yr)						
Conventional Radiocarbon Age (BP)	20	20	100	1,900	9,800	6,600

Notes:
1 = Total solids analysis was additionally conducted on the volatile petroleum hydrocarbon and carbon isotope samples, resulting in an additional 14 samples.
J = estimated value
Percent detected results are rounded to the nearest whole number. Minimum, maximum, and average results are rounded to two significant figures, except where trailing zeros are not shown, resulting in one significant figure.
Qualifiers are not shown on average results.

Acronyms:
µg/kg = micrograms per kilogram
BP = before present
CFU/g = colony-forming units per gram
HEM = n-hexane extractable material
lb/ft^3 = pounds per cubic foot
mg/kg = milligrams per kilogram
per mil HOx2 = parts per thousand Homeobox-leucine zipper protein; National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) 4990C
per mil VPDB = parts per thousand Vienna Pee Dee Belemnite
pMC = percent modern carbon
wt% = weight percent
yr = year

Table D4-5b
Gas Ebullition Porewater Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
Conventional Parameters (porewater) (psu)						
Salinity	20	20	100	11 J	24 J	20
Conventional Parameters (porewater) (mg/L)						
Bromide	20	20	100	32 J	45 J	37
Chloride	20	20	100	12,000 J	16,000 J	14,000
Dissolved organic carbon	20	20	100	6.2 J	110 J	41
Sulfate[1]	17	17	100	1.4 J	770 J	240
Isotope Ratios (porewater) (per mil VPDB)						
d13C of dissolved inorganic carbon	20	20	100	-15	24	11

Notes:
1 = Three porewater sulfate results from core NC342SC-H were rejected due to excessive hold time exceedances from sample collection to centrifuging.
J = estimated value
Percent detected results are rounded to the nearest whole number. Minimum, maximum, and average results are rounded to two significant figures, except where trailing zeros are not shown, resulting in one significant figure. Qualifiers are not shown on average results.

Acronyms:
mg/L = milligrams per liter
per mil VPDB = parts per thousand Vienna Pee Dee Belemnite
psu = practical salinity units

Table D4-5c
Gas Ebullition Surface Water Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
Conventional Parameters (psu)						
Salinity	2	2	100	22 J	24	23
Conventional Parameters (mg/L)						
Bromide	2	2	100	37	42 J	40
Chloride	2	2	100	14,000	15,000 J	15,000
Methane	2	2	100	0.0063	0.073	0.04
Particulate organic carbon (POC)	2	2	100	2.8	2.8	2.8
Sulfate	2	2	100	1,600	2,000	1,800
Total organic carbon	2	2	100	1.2 J	1.6 J	1.4
Total suspended solids	2	2	100	13	16	15
Conventional Parameters, Dissolved (mg/L)						
Dissolved organic carbon	2	2	100	1.2 J	1.7 J	1.5
Pathogens (CFU/mL)						
Clostridium perfringens	2	0	0	--	--	--
Polycyclic Aromatic Hydrocarbons (µg/L)						
1-Methyldibenzothiophene	2	1	50	0.0026 J	0.0026 J	0.0026
1-Methylnaphthalene	2	0	0	--	--	--
1-Methylphenanthrene	2	1	50	0.0017 J	0.0017 J	0.0017
2,3,5-Trimethylnaphthalene (1,6,7-Trimethylnaphthalene)	2	1	50	0.025	0.025	0.025
2,6-Dimethylnaphthalene	2	2	100	0.0067 J	0.0085 J	0.0076
2-Methylanthracene	2	1	50	0.0017 J	0.0017 J	0.0017
2-Methyldibenzothiophene & 3-Methyldibenzothiophene	2	0	0	--	--	--
2-Methylnaphthalene	2	0	0	--	--	--
2-Methylphenanthrene	2	1	50	0.0014 J	0.0014 J	0.0014
4-Methyldibenzothiophene	2	1	50	0.0027 J	0.0027 J	0.0027
4-Methylphenanthrene & 9-Methylphenanthrene	2	1	50	0.0028 J	0.0028 J	0.0028
Acenaphthene	2	2	100	0.055	0.088	0.072
Acenaphthylene	2	2	100	0.0026 J	0.0051 J	0.0039
Anthracene	2	2	100	0.0048 J	0.0071 J	0.0059
Benzo(a)anthracene	2	2	100	0.0022 J	0.01 J	0.0061
Benzo(a)pyrene	2	2	100	0.0038 J	0.0099 J	0.0068
Benzo(b)fluoranthene	2	1	50	0.0034 J	0.0034 J	0.0034
Benzo(e)pyrene	2	1	50	0.0045 J	0.0045 J	0.0045
Benzo(g,h,i)perylene	2	1	50	0.004 J	0.004 J	0.004
Benzo(j,k)fluoranthene	2	2	100	0.0032 J	0.008 J	0.0056
Benzothiophene	2	0	0	--	--	--
Biphenyl (1,1'-Biphenyl)	2	1	50	0.0036 J	0.0036 J	0.0036
Carbazole	2	1	50	0.0096 J	0.0096 J	0.0096
Chrysene	2	2	100	0.004 J	0.012	0.008
Decalin, cis- & trans-	2	1	50	0.0056	0.0056	0.0056
Dibenzo(a,h)anthracene and Dibenzo(a,c)anthracene	2	0	0	--	--	--
Dibenzothiophene	2	2	100	0.0032 J	0.0041 J	0.0036
Fluoranthene	2	2	100	0.021	0.028	0.024
Fluorene	2	2	100	0.0047 J	0.0047 J	0.0047
Indeno(1,2,3-c,d)pyrene	2	1	50	0.0044 J	0.0044 J	0.0044

Table D4-5c
Gas Ebullition Surface Water Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
Naphthalene	2	2	100	0.0038 J	0.0063 J	0.005
Naphthobenzothiophene	2	1	50	0.0043 J	0.0043 J	0.0043
Perylene	2	1	50	0.003 J	0.003 J	0.003
Phenanthrene	2	1	50	0.0044 J	0.0044 J	0.0044
Pyrene	2	2	100	0.021	0.03	0.025
Retene	2	0	0	--	--	--
Alkylated Polycyclic Aromatic Hydrocarbons (µg/L)						
C1-Benzanthracenes/Chrysenes	2	1	50	0.011	0.011	0.011
C1-Benzo(b)thiophene	2	0	0	--	--	--
C1-Decalins	2	0	0	--	--	--
C1-Dibenzothiophenes	2	1	50	0.013	0.013	0.013
C1-Fluoranthenes/Pyrenes	2	2	100	0.019	0.024	0.022
C1-Fluorenes	2	0	0	--	--	--
C1-Naphthalenes	2	0	0	--	--	--
C1-Phenanthrenes/Anthracenes	2	1	50	0.013	0.013	0.013
C2-Benzanthracenes/Chrysenes	2	0	0	--	--	--
C2-Benzo(b)thiophene	2	0	0	--	--	--
C2-Decalins	2	0	0	--	--	--
C2-Dibenzothiophenes	2	1	50	0.026	0.026	0.026
C2-Fluorenes	2	0	0	--	--	--
C2-Naphthalenes	2	0	0	--	--	--
C2-Phenanthrenes/Anthracenes	2	0	0	--	--	--
C3-Benzanthracenes/Chrysenes	2	0	0	--	--	--
C3-Benzo(b)thiophene	2	0	0	--	--	--
C3-Decalins	2	0	0	--	--	--
C3-Dibenzothiophenes	2	0	0	--	--	--
C3-Fluorenes	2	0	0	--	--	--
C3-Naphthalenes	2	0	0	--	--	--
C3-Phenanthrenes/Anthracenes	2	0	0	--	--	--
C4-Benzanthracenes/Chrysenes	2	0	0	--	--	--
C4-Benzo(b)thiophene	2	0	0	--	--	--
C4-Decalins	2	0	0	--	--	--
C4-Dibenzothiophenes	2	0	0	--	--	--
C4-Naphthalenes	2	0	0	--	--	--
C4-Phenanthrenes/Anthracenes	2	0	0	--	--	--
n-Alkanes and Isoprenoids (µg/L)						
2,6,10-Trimethyldodecane	2	0	0	--	--	--
2,6,10-Trimethyltridecane	2	0	0	--	--	--
n-Decane (C10)	2	0	0	--	--	--
n-Docosane (C22)	2	0	0	--	--	--
n-Dodecane (C12)	2	0	0	--	--	--
n-Dotriacontane (C32)	2	0	0	--	--	--
n-Eicosane (C20)	2	0	0	--	--	--
n-Heneicosane (C21)	2	0	0	--	--	--
n-Hentriacontane (C31)	2	0	0	--	--	--

Table D4-5c
Gas Ebullition Surface Water Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
n-Heptacosane (C27)	2	0	0	--	--	--
n-Heptadecane (C17)	2	0	0	--	--	--
n-Heptatriacontane (C37)	2	0	0	--	--	--
n-Hexacosane (C26)	2	0	0	--	--	--
n-Hexadecane (C16)	2	0	0	--	--	--
n-Hexatriacontane (C36)	2	0	0	--	--	--
n-Nonacosane (C29)	2	0	0	--	--	--
n-Nonadecane (C19)	2	0	0	--	--	--
n-Nonane (C9)	2	0	0	--	--	--
n-Nonatriacontane (C39)	2	0	0	--	--	--
n-Octacosane (C28)	2	0	0	--	--	--
n-Octadecane (C18)	2	0	0	--	--	--
n-Octatriacontane (C38)	2	0	0	--	--	--
n-Pentacosane (C25)	2	0	0	--	--	--
n-Pentadecane (C15)	2	1	50	0.18 J	0.18 J	0.18
n-Pentatriacontane (C35)	2	0	0	--	--	--
n-Tetracontane (C40)	2	0	0	--	--	--
n-Tetracosane (C24)	2	0	0	--	--	--
n-Tetradecane (C14)	2	0	0	--	--	--
n-Tetratriacontane (C34)	2	0	0	--	--	--
n-Triacontane (C30)	2	0	0	--	--	--
n-Tricosane (C23)	2	1	50	0.12 J	0.12 J	0.12
n-Tridecane (C13)	2	0	0	--	--	--
n-Tritriacontane (C33)	2	0	0	--	--	--
n-Undecane (C11)	2	0	0	--	--	--
Norpristane	2	0	0	--	--	--
Phytane	2	0	0	--	--	--
Pristane	2	0	0	--	--	--
Extractable Petroleum Hydrocarbons (mg/L)						
C9-C18 Aliphatics unadjusted	2	0	0	--	--	--
C19-C36 Aliphatics unadjusted	2	0	0	--	--	--
C11-C22 Aromatics adjusted	2	0	0	--	--	--
C11-C22 Aromatics unadjusted	2	0	0	--	--	--
Volatile Petroleum Hydrocarbons (mg/L)						
C5-C8 Aliphatics adjusted	1	0	0	--	--	--
C5-C8 Aliphatics unadjusted	1	0	0	--	--	--
C9-C12 Aliphatics adjusted	1	0	0	--	--	--
C9-C12 Aliphatics unadjusted	1	0	0	--	--	--
C9-C10 Aromatics unadjusted	1	0	0	--	--	--

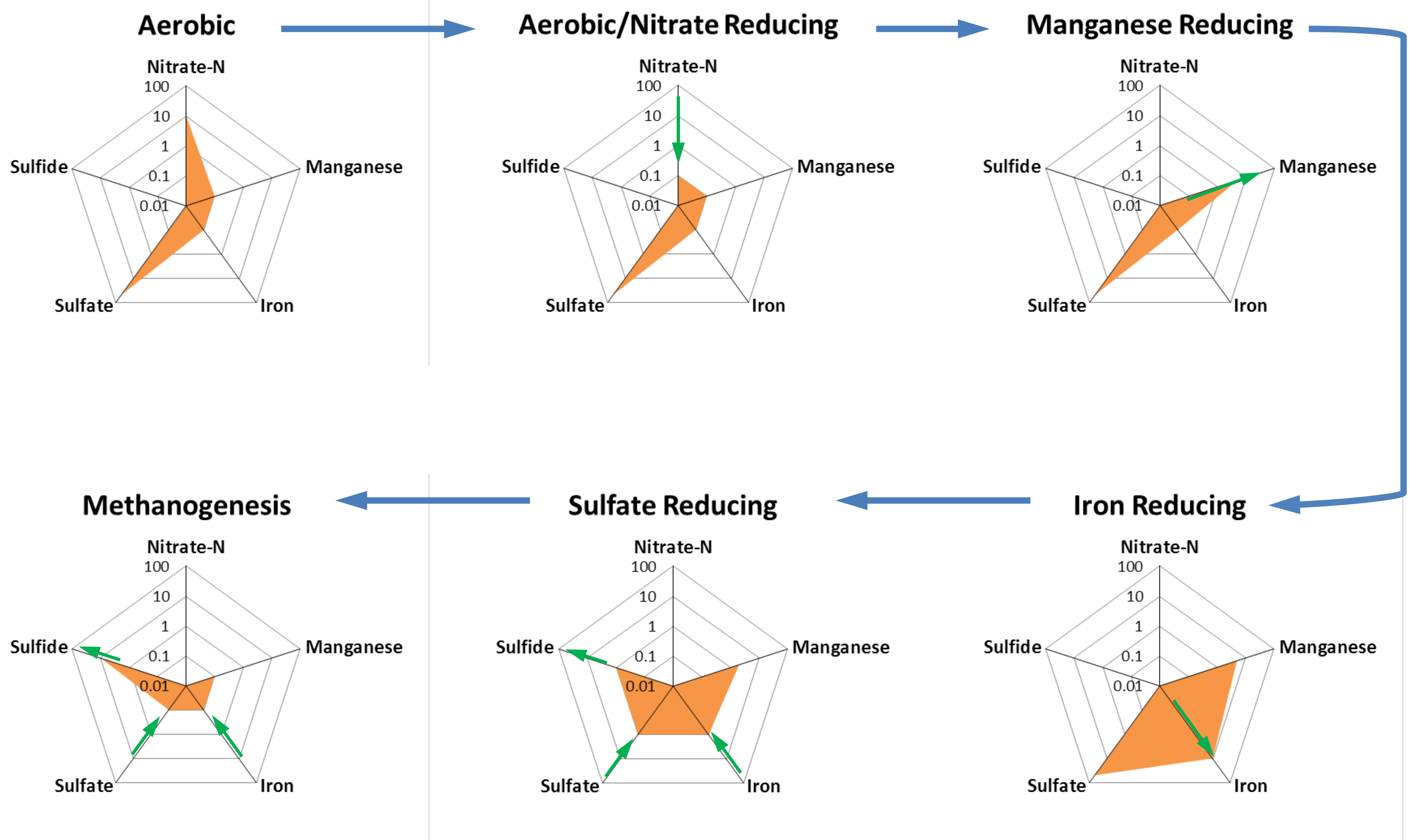
Table D4-5c
Gas Ebullition Surface Water Results Summary

Analyte	Count Results	Count Detects	Percent Detected	Minimum Detected Result	Maximum Detected Result	Arithmetic Average Detected Result
Total Petroleum Hydrocarbons (mg/L)						
Diesel range organics (C10-C28)	2	2	100	0.07	0.071	0.07
Total petroleum hydrocarbons (C9-C40)	2	1	50	0.082	0.082	0.082
Isotope Ratios (none)						
Fraction Modern Carbon (fMDN)	2	2	100	0.96	1	0.98
Isotope Ratios (per mil VPDB)						
d13C of dissolved inorganic carbon	2	2	100	-6.2	-5.2	-5.7
Isotope Ratios (per mil VSMOW)						
d18O	2	2	100	-3	-2.9	-3
dD	2	2	100	-20	-18	-19
Isotope Ratios (pMC)						
Carbon-14 of dissolved inorganic carbon	2	2	100	96	100	98
Isotope Ratios (yr)						
Apparent Radiocarbon Age (BP)	2	2	100	-40	370	170

Notes:
-- = indicates no information that is appropriate or available
J = estimated value
Percent detected results are rounded to the nearest whole number. Minimum, maximum, and average results are rounded to two significant figures, except where trailing zeros are not shown, resulting in one significant figure. Qualifiers are not shown on average results.
By convention, Year 0 for apparent radiocarbon age (BP) is 1950. Negative BP values indicate the number of years post-1950.

Acronyms:
µg/L = micrograms per liter
BP = before present
CFU/mL = colony-forming units per milliliter
mg/L = milligrams per liter
per mil VPDB = parts per thousand Vienna Pee Dee Belemnite
per mil VSMOW = parts per thousand Vienna Standard Mean Ocean Water
pMC = percent modern carbon
psu = practical salinity unit
yr = year

FIGURES



Notes: Concentrations are conceptual in milligrams per liter. The figure was created based on compiled information from relevant sources (Chapelle 2001, Emerson and Hedges 2003, Salminen et al. 2006).

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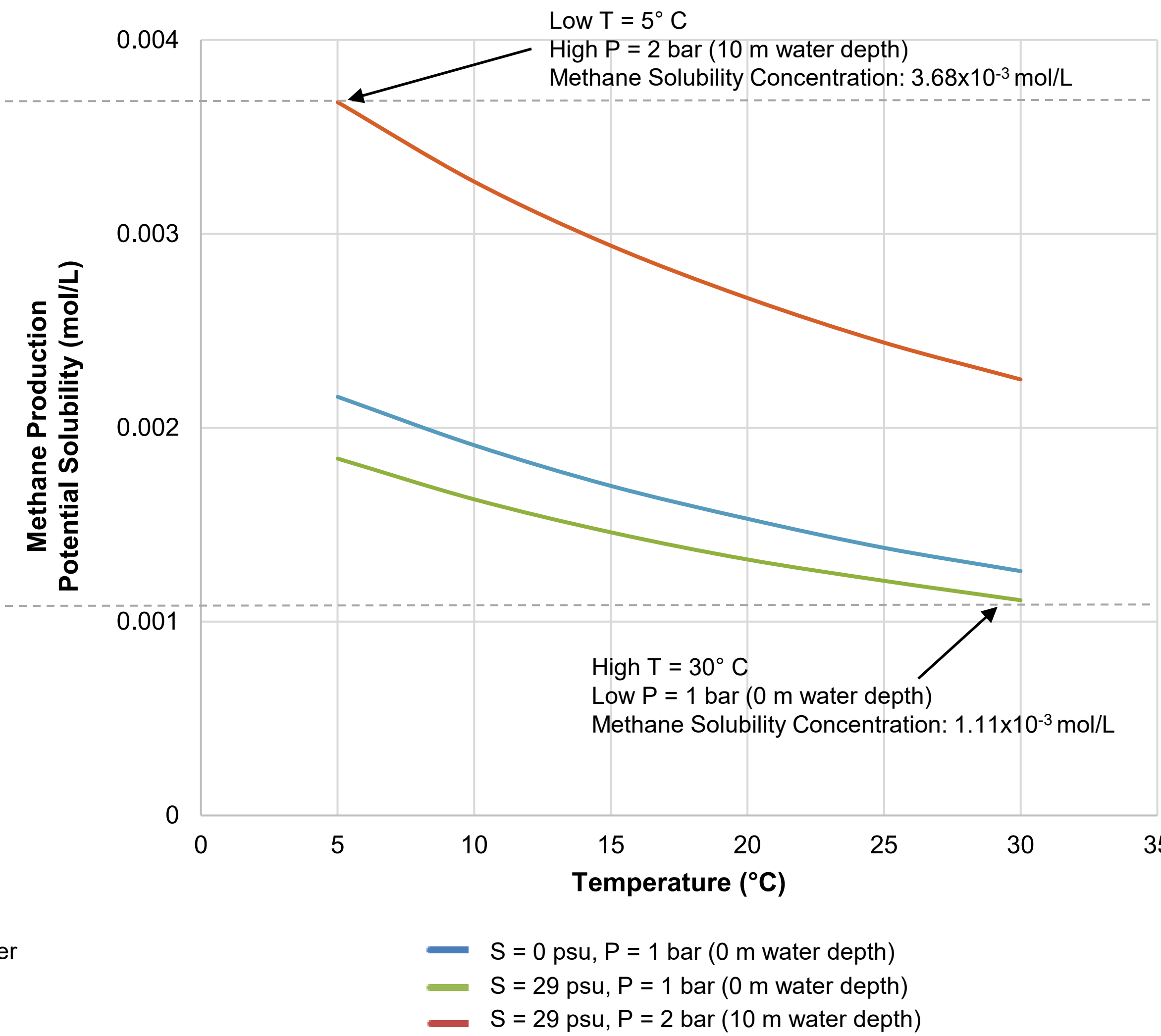
Figure D2-1
Electron Acceptor Utilization Pattern
Gas Ebullition Evaluation
Newtown Creek RI/FS

Gas ebullition **is possible** in this zone. If all excess DOC were to be converted to methane and carbon dioxide, it would exceed methane solubility for any combination of temperature, pressure, and salinity

Gas ebullition **may be** possible in this zone. If all excess DOC were to be converted to methane and carbon dioxide, it could exceed methane solubility for some combinations of temperature, pressure, and salinity

Gas ebullition **is not** possible in this zone. Even if all excess DOC were to be converted to methane and carbon dioxide, it would not be sufficient to exceed gas solubility and form bubbles under any combination of temperature, pressure, and salinity.



Notes:
The solubility plot was developed using results of the Duan and Mao (2006) model for calculating methane solubility.

DOC = dissolved organic carbon in porewater or groundwater
m = meter
mol/L = mole per liter
P = pressure
psu = practical salinity unit
S = salinity
T = temperature

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Figure D2-2
Methane Solubility versus Temperature and Pressure
Gas Ebullition Evaluation
Newtown Creek RI/FS

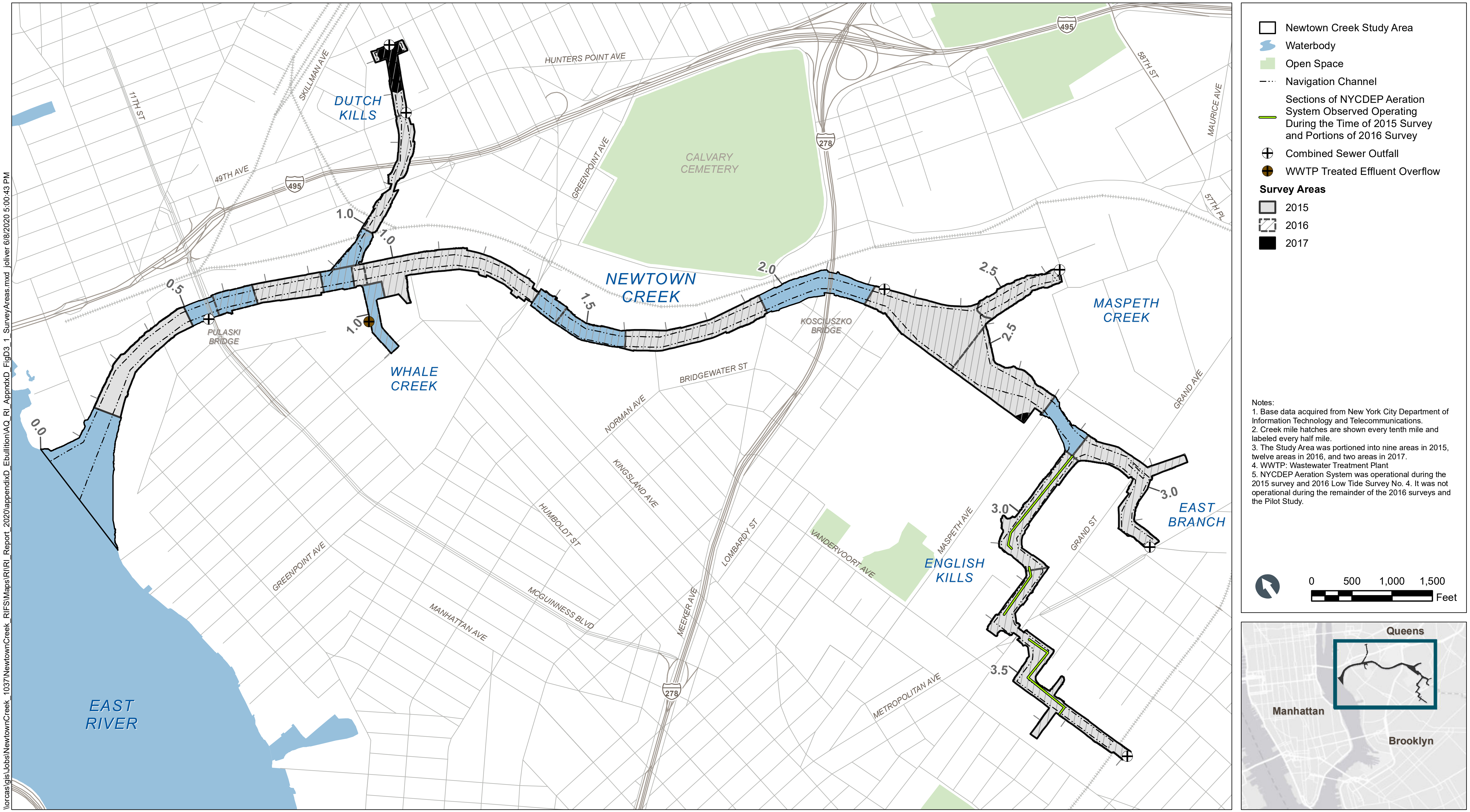

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Figure D3-1
Field Gas Ebullition Survey Areas – 2015, 2016, and 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS

East Branch Survey Area

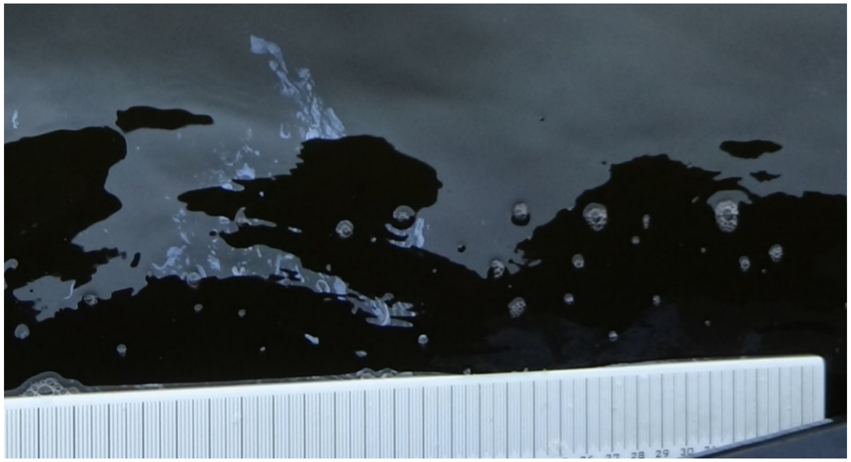
Dynamic Sheen: Silvery, non-brittle

Whale Creek Survey Area

Dynamic Sheen: Silvery, non-brittle

CM 1.6 to 1.94 Survey Area

Static Sheen: Silvery, non-brittle, contiguous



Turning Basin Survey Area

Static Sheen: Rainbow, brittle, spotty

Note: Sheens that develop on the water surface are classified as dynamic sheens (with or without a breaking gas bubble), whereas static sheens float on the water surface into the observation area.

Figure D3-2
Examples of Representative Sheen Observations
Gas Ebullition Evaluation
Newtown Creek RI/FS

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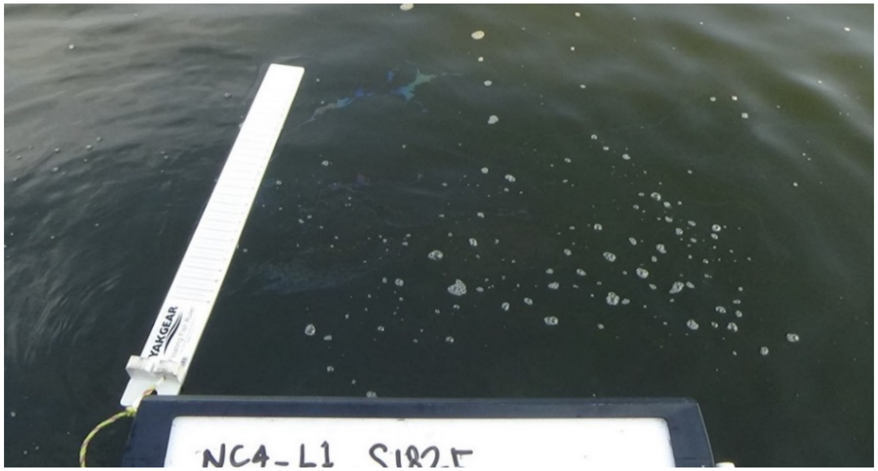
English Kills Survey Area

Apparent Gas Ebullition

English Kills Survey Area

Gas bubbles associated with aeration system operation



CM 1.6 to 1.94 Survey Area

Apparent Gas Ebullition

Maspeth Creek Survey Area

Apparent Gas Ebullition

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Figure D3-3
Examples of Representative Apparent Gas Ebullition Observations
Gas Ebullition Evaluation
Newtown Creek RI/FS

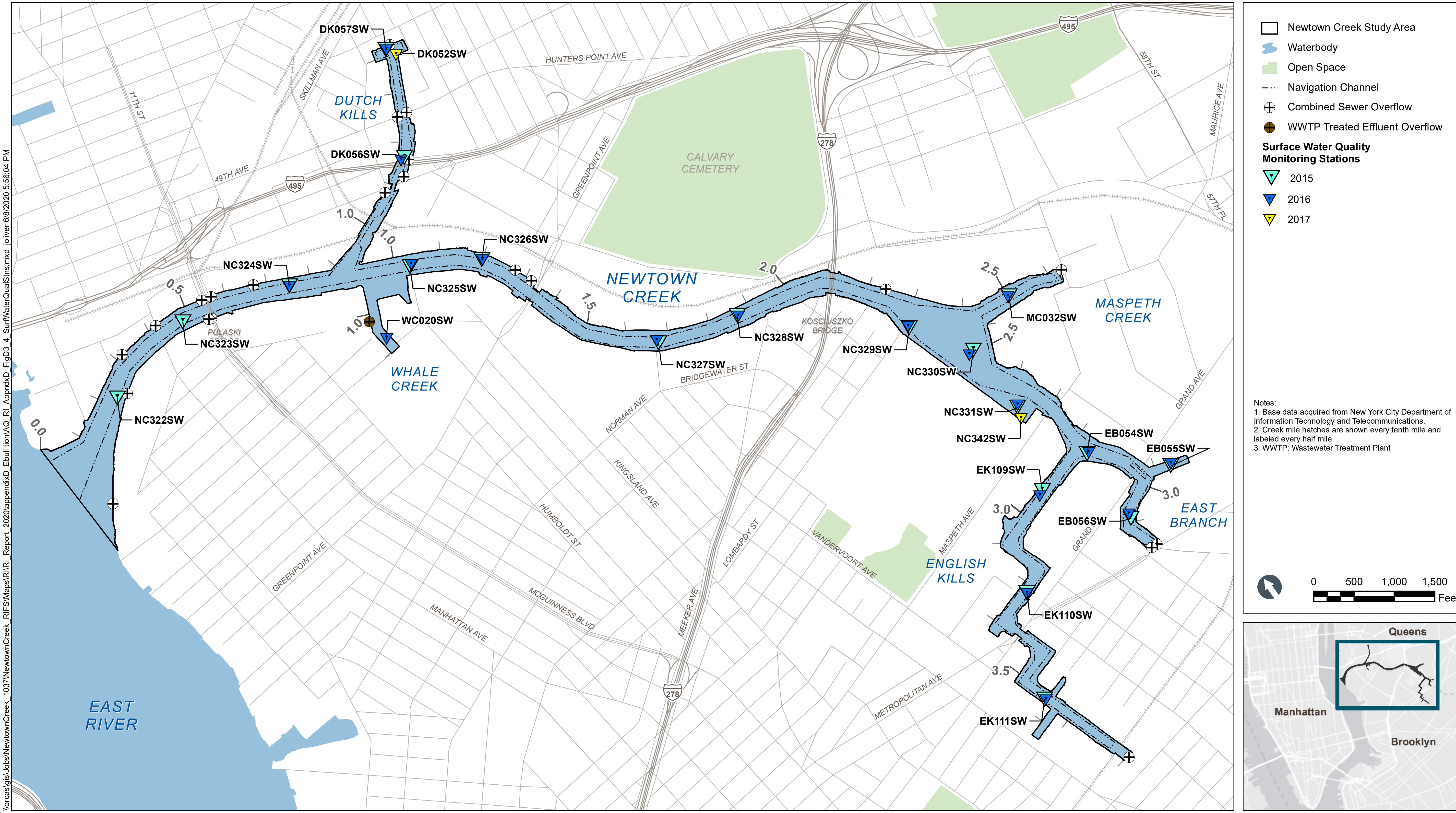

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Figure D3-4
Field Gas Ebullition Survey Surface Water Quality Monitoring Stations – 2015, 2016, and 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS

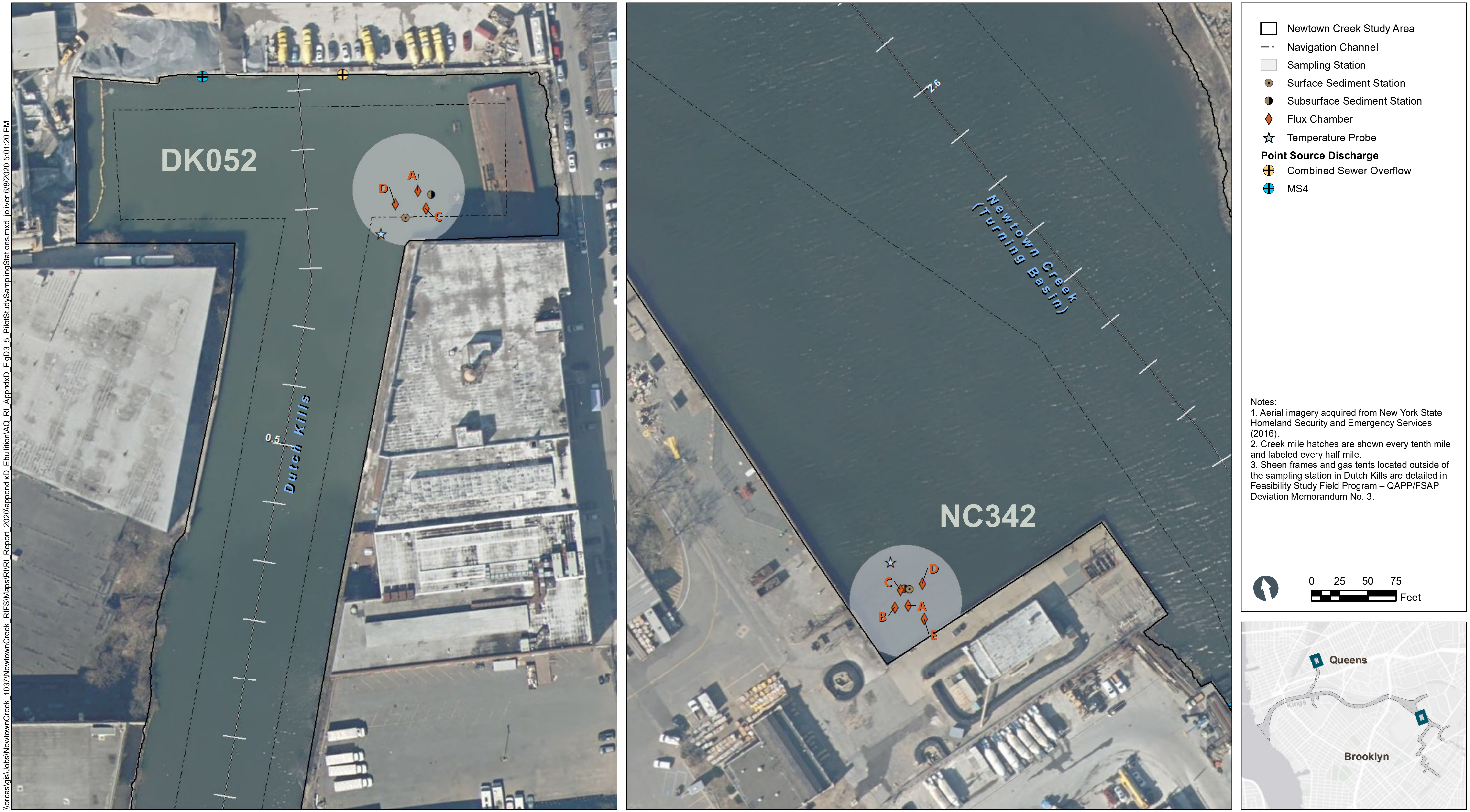

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Figure D3-5
Pilot Study Sampling Stations
Gas Ebullition Evaluation
Newtown Creek RI/FS

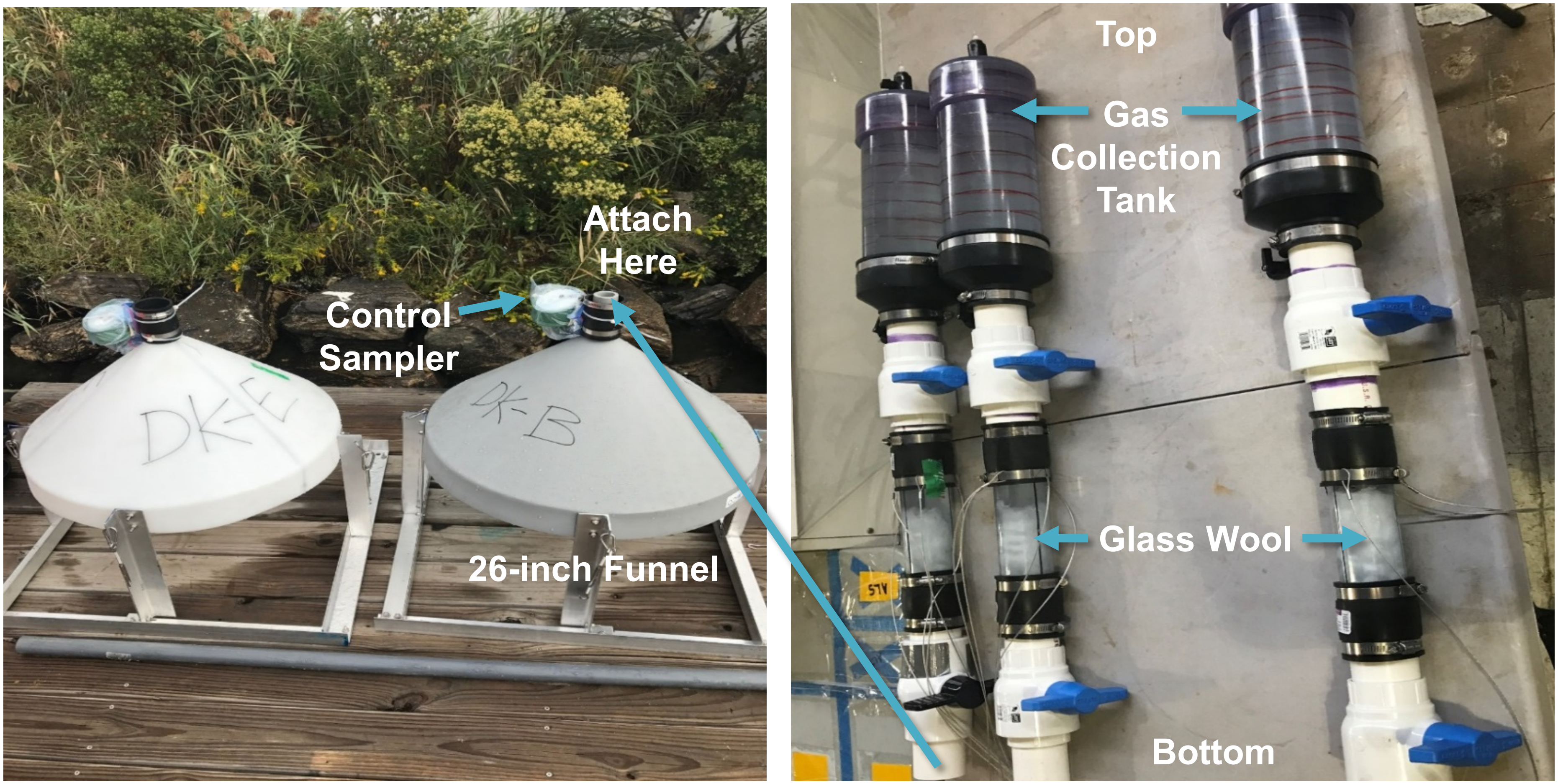

Figure D3-6
Flux Chamber Sampling Equipment Photographs
Gas Ebullition Evaluation
Newtown Creek RI/FS

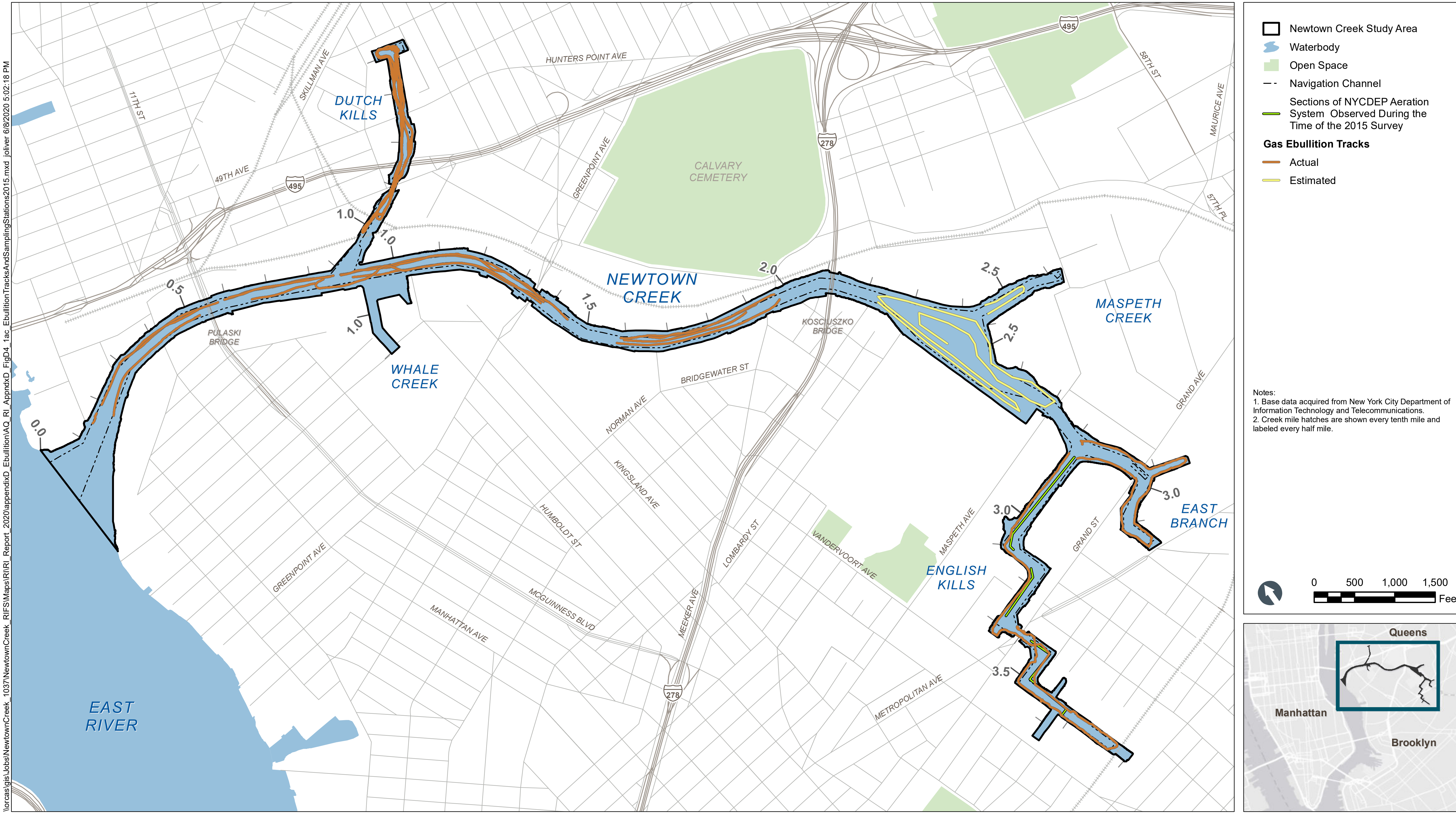

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Figure D4-1a
Field Gas Ebullition Survey Tracks – 2015 High Tide Survey No. 1
Gas Ebullition Evaluation
Newtown Creek RI/FS

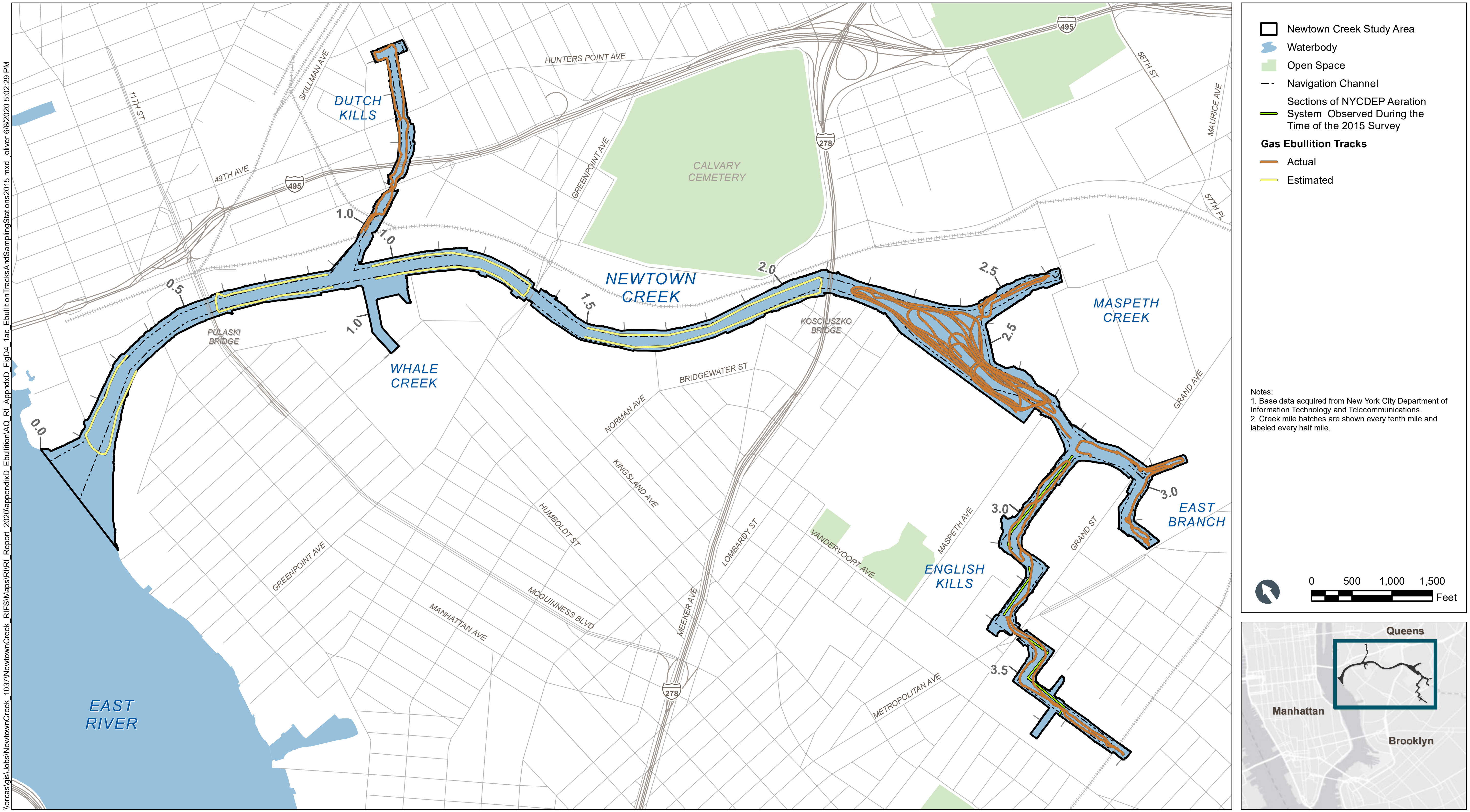

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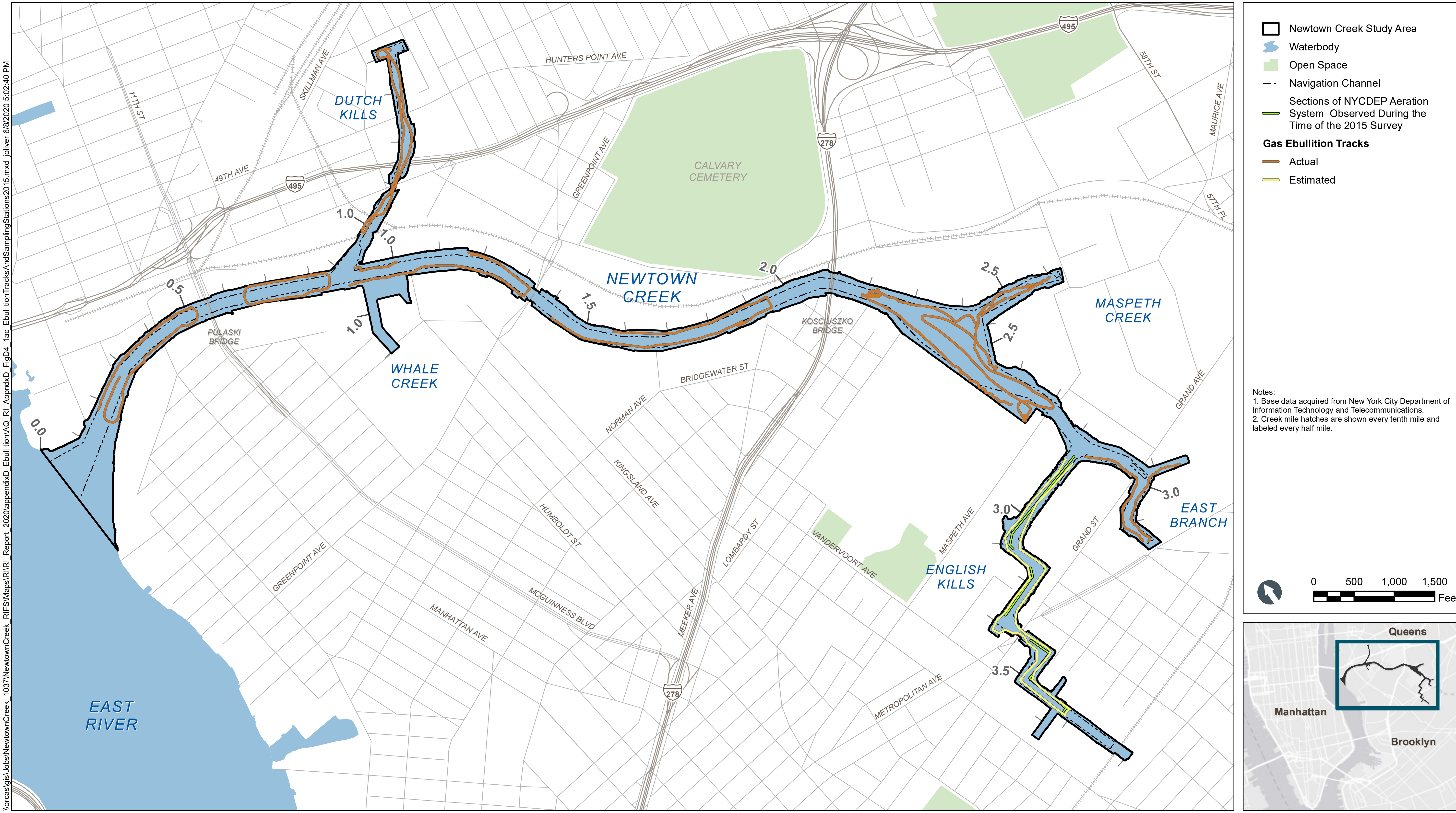
Figure D4-1b
Field Gas Ebullition Survey Tracks – 2015 Low Tide Survey No. 1
Gas Ebullition Evaluation
Newtown Creek RI/FS



\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_EbullitionAQ_RI_AppndxD_FigD4_1ac_EbullitionTracksAndSamplingStations2015.mxd joliver 6/8/2020 5:02:40 PM

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Figure D4-1c
Field Gas Ebullition Survey Tracks – 2015 Low Tide Survey No. 2
Gas Ebullition Evaluation
Newtown Creek RI/FS

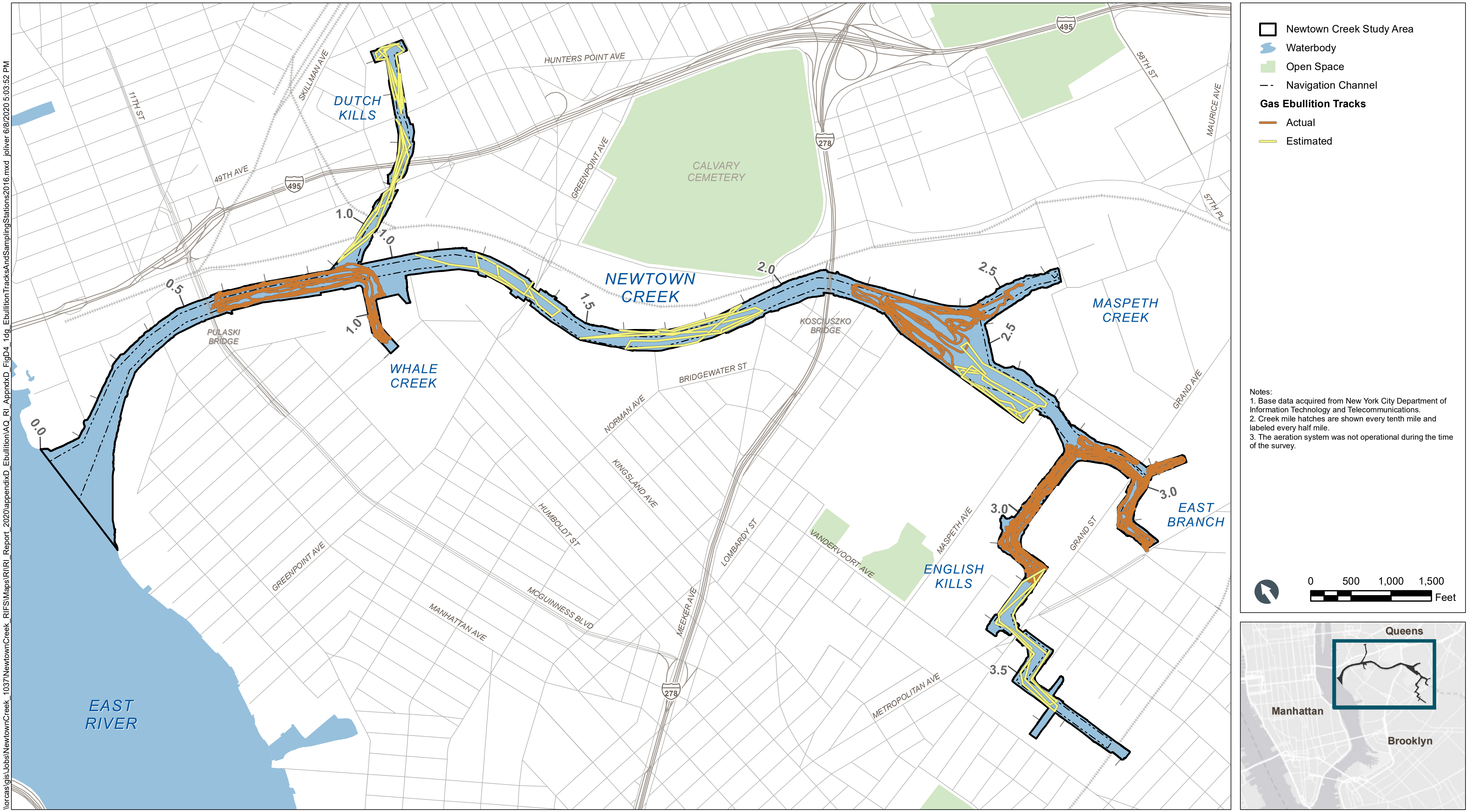

Figure D4-1d
Field Gas Ebullition Survey Tracks – 2016 Low Tide Survey No. 1
Gas Ebullition Evaluation
Newtown Creek RI/FS

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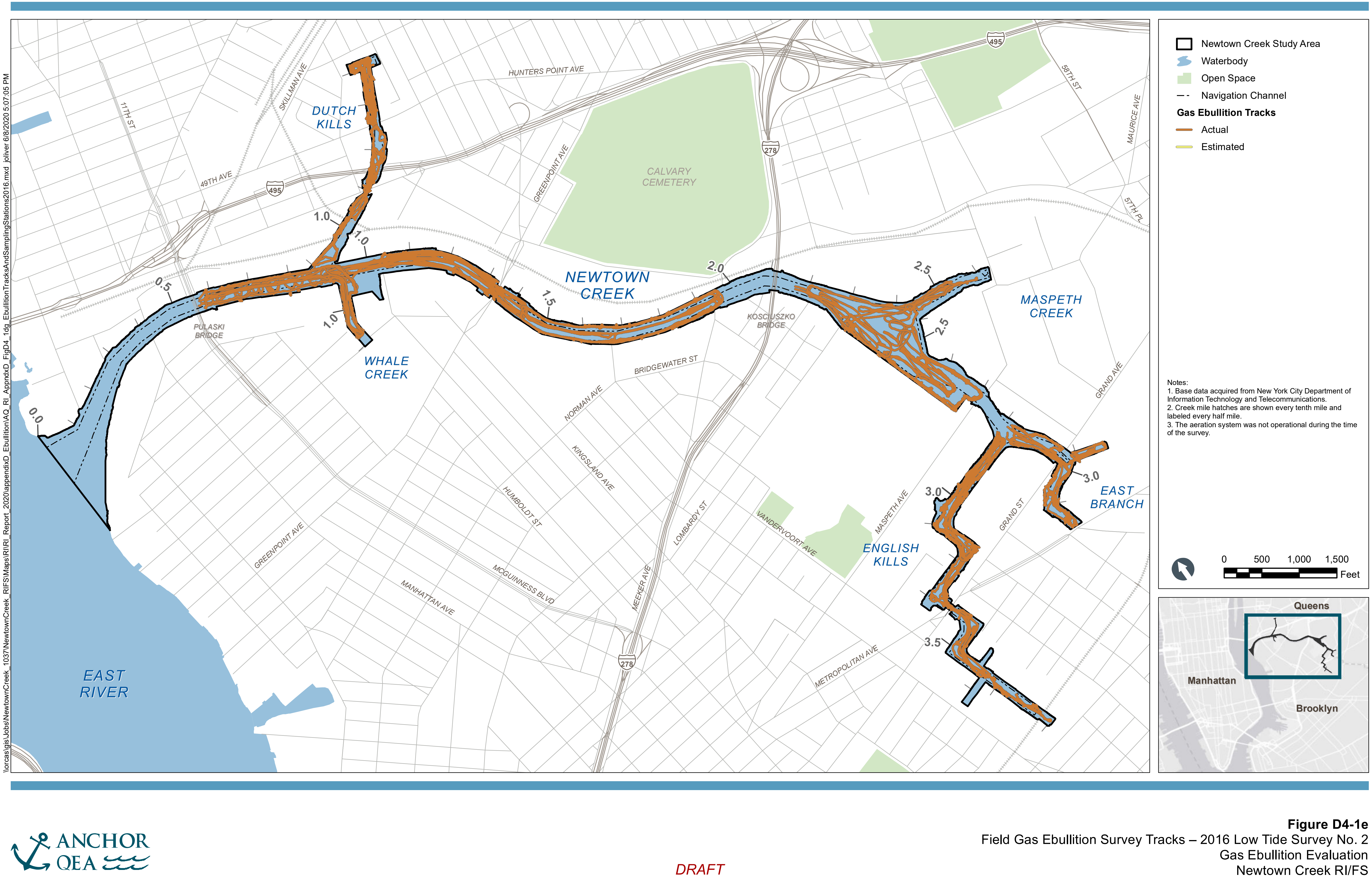

Figure D4-1e
Field Gas Ebullition Survey Tracks – 2016 Low Tide Survey No. 2
Gas Ebullition Evaluation
Newtown Creek RI/FS

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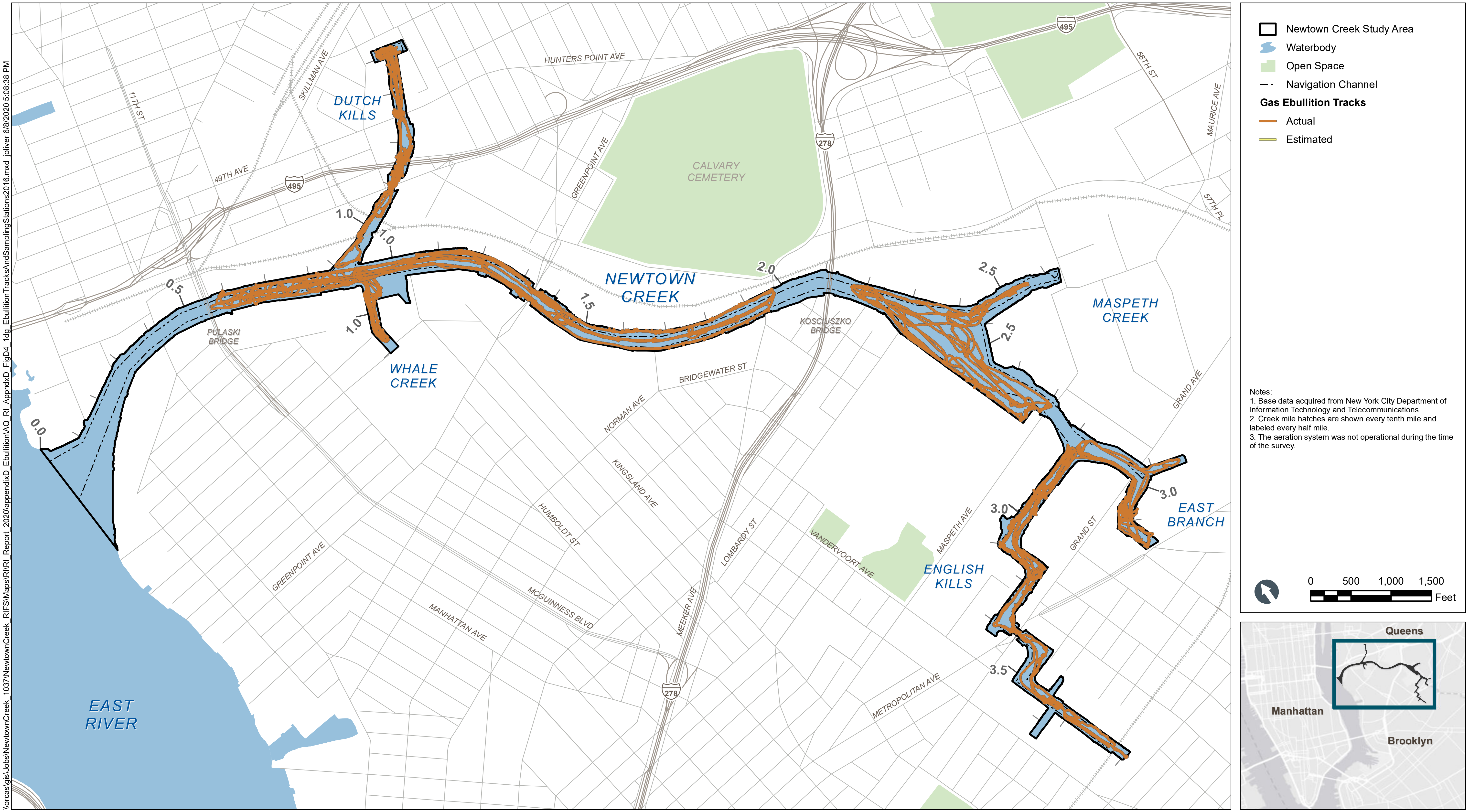

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Figure D4-1f
Field Gas Ebullition Survey Tracks – 2016 Low Tide Survey No. 3
Gas Ebullition Evaluation
Newtown Creek RI/FS

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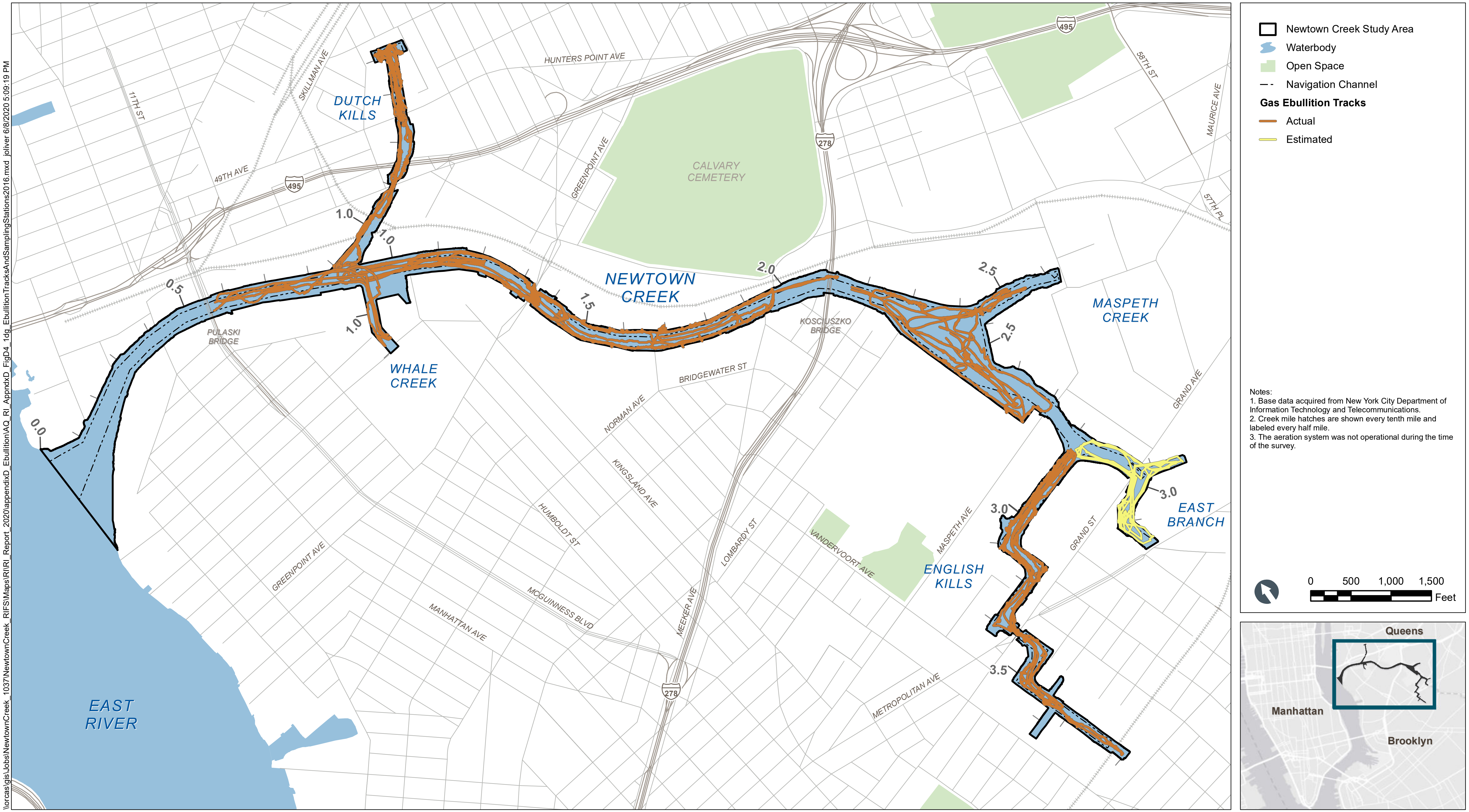

Notes:
1. Base data acquired from New York City Department of Information Technology and Telecommunications.
2. Creek mile hatches are shown every tenth mile and labeled every half mile.
3. The aeration system was not operational during the time of the survey.

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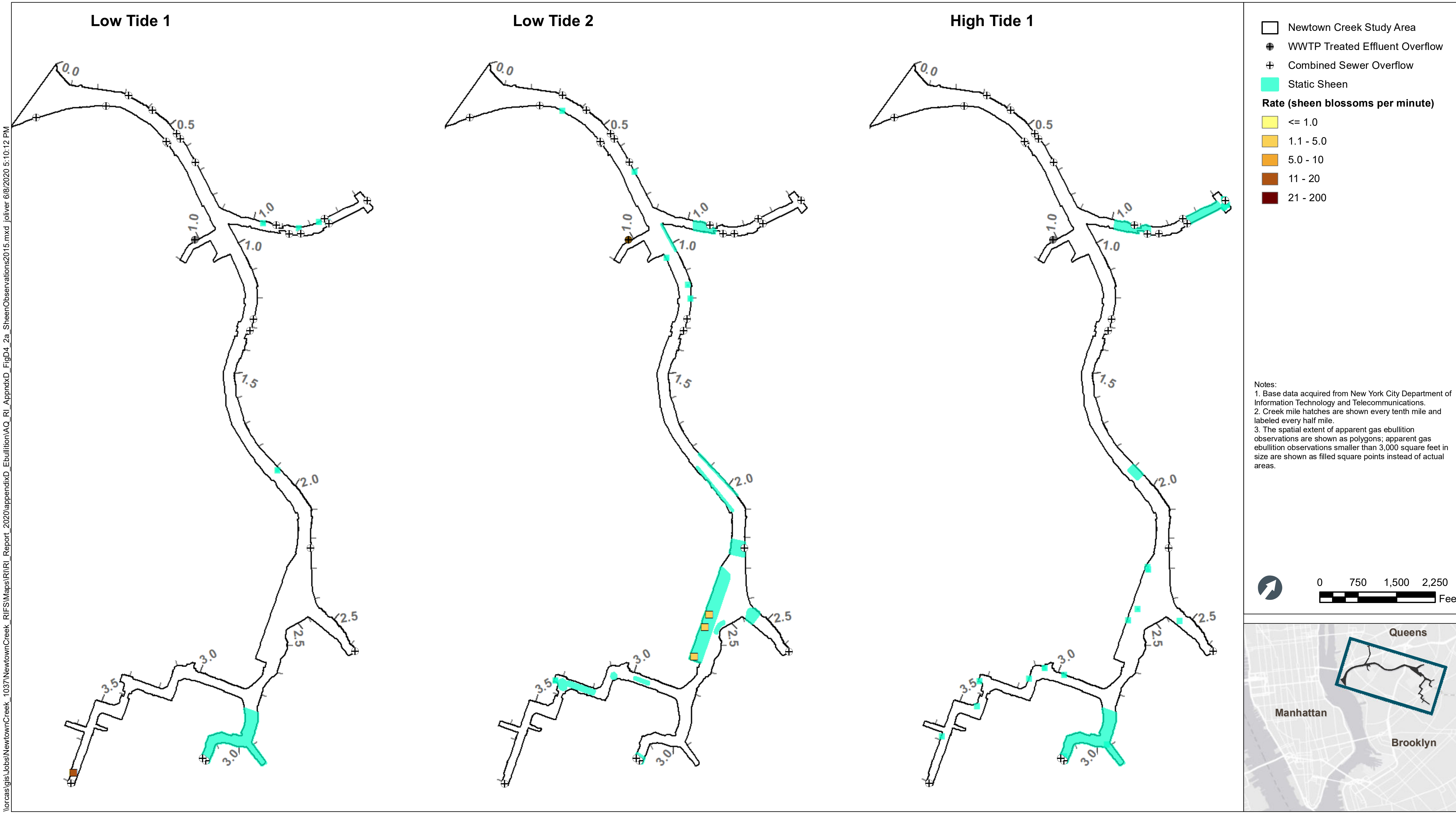
Figure D4-1g
Field Gas Ebullition Survey Tracks – 2016 Low Tide Survey No. 4
Gas Ebullition Evaluation
Newtown Creek RI/FS



Notes:
1. Base data acquired from New York City Department of Information Technology and Telecommunications.
2. Creek mile hatches are shown every tenth mile and labeled every half mile.
3. The spatial extent of apparent gas ebullition observations are shown as polygons; apparent gas ebullition observations smaller than 3,000 square feet in size are shown as filled square points instead of actual areas.

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Figure D4-2a
Sheen Observations – 2015
Gas Ebullition Evaluation
Newtown Creek RI/FS

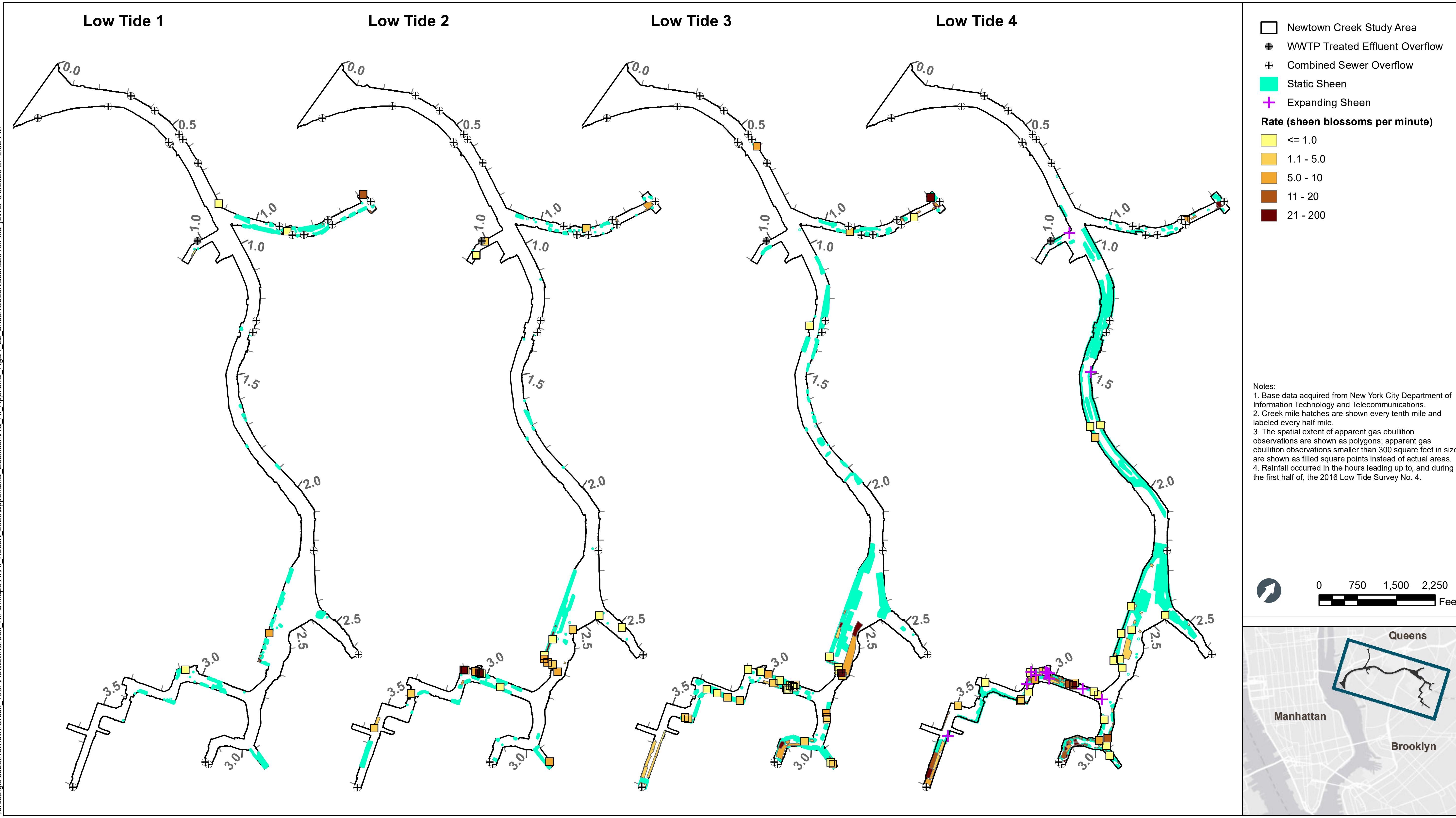

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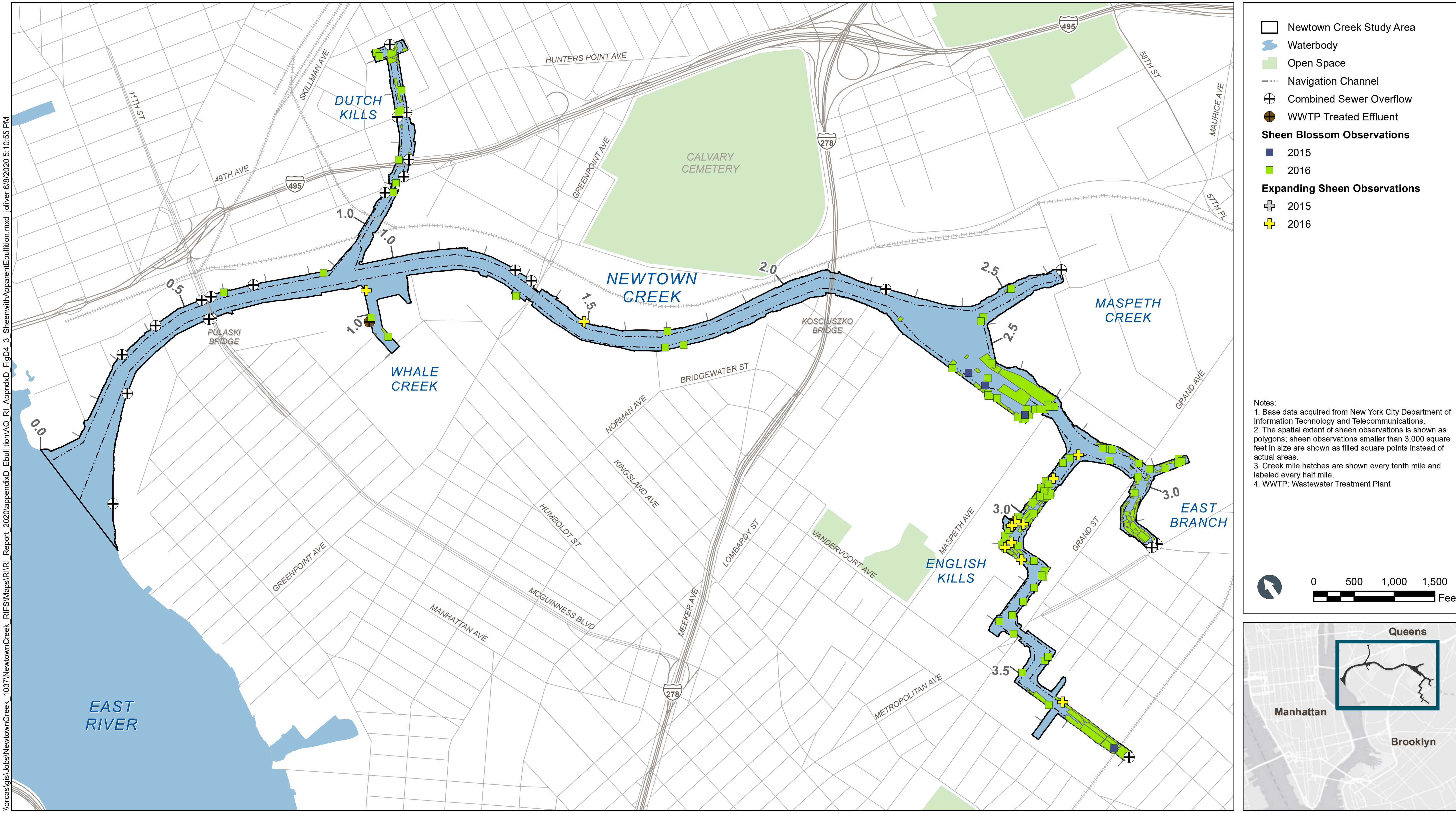
Figure D4-2b
Sheen Observations – 2016
Gas Ebullition Evaluation
Newtown Creek RI/FS



Notes:
1. Base data acquired from New York City Department of Information Technology and Telecommunications.
2. The spatial extent of sheen observations is shown as polygons; sheen observations smaller than 3,000 square feet in size are shown as filled square points instead of actual areas.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. WWTP: Wastewater Treatment Plant

\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_Ebullition\AQ_RI_AppndxD_FigD4_3_SheenwithApparentEbullition.mxd joliver 6/8/2020 5:10:55 PM

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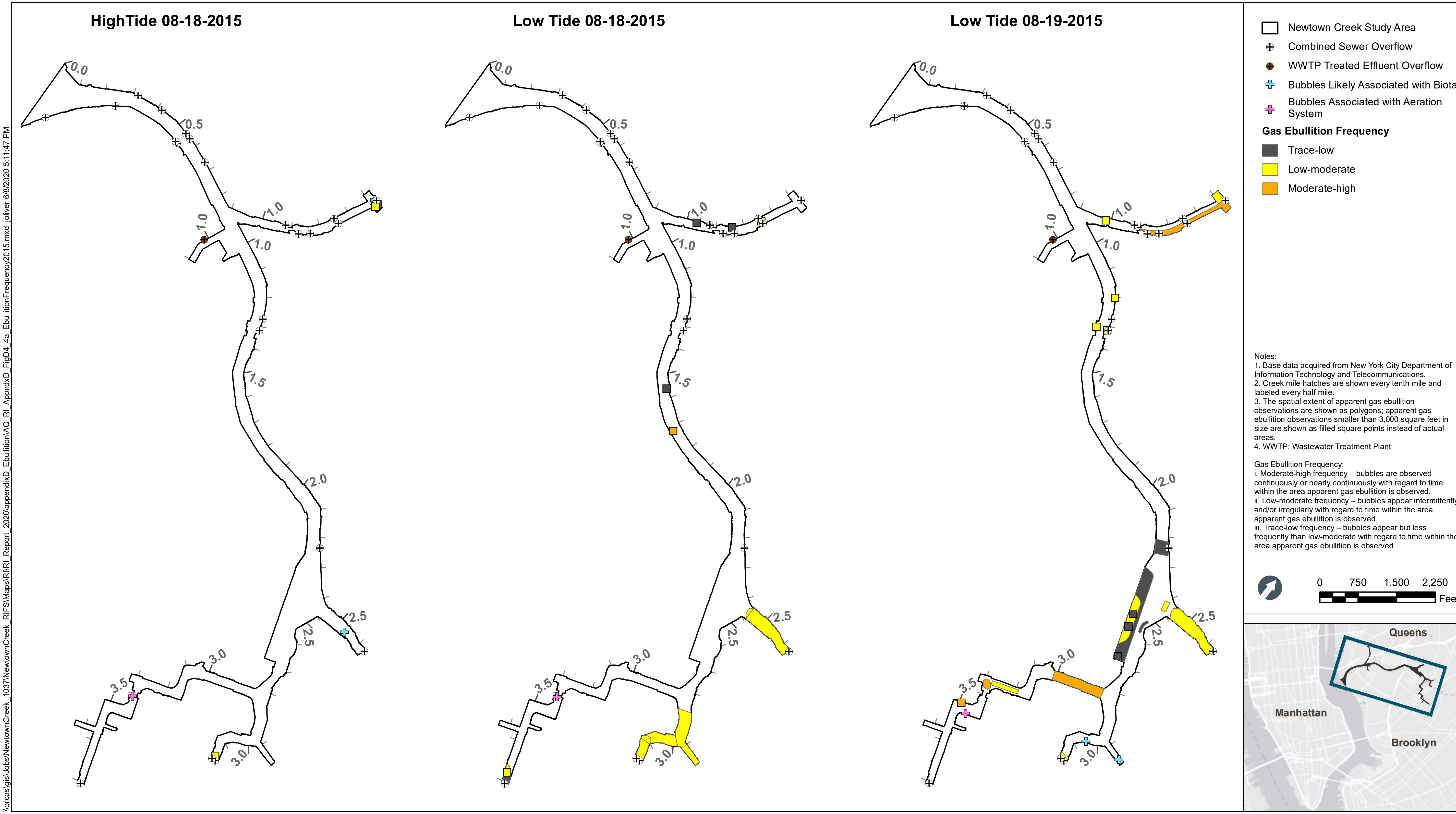
Figure D4-3
Summary of 2015 and 2016 Dynamic Sheen Observations for All Surveys
Gas Ebullition Evaluation
Newtown Creek RI/FS



\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_Ebullition\AQ_RI_AppndxD_FigD4_4a_EbullitionFrequency2015.mxd joliver 6/8/2020 5:11:47 PM

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Figure D4-4a
Apparent Gas Ebullition Observations by Gas Bubble Frequency – 2015
Gas Ebullition Evaluation
Newtown Creek RI/FS

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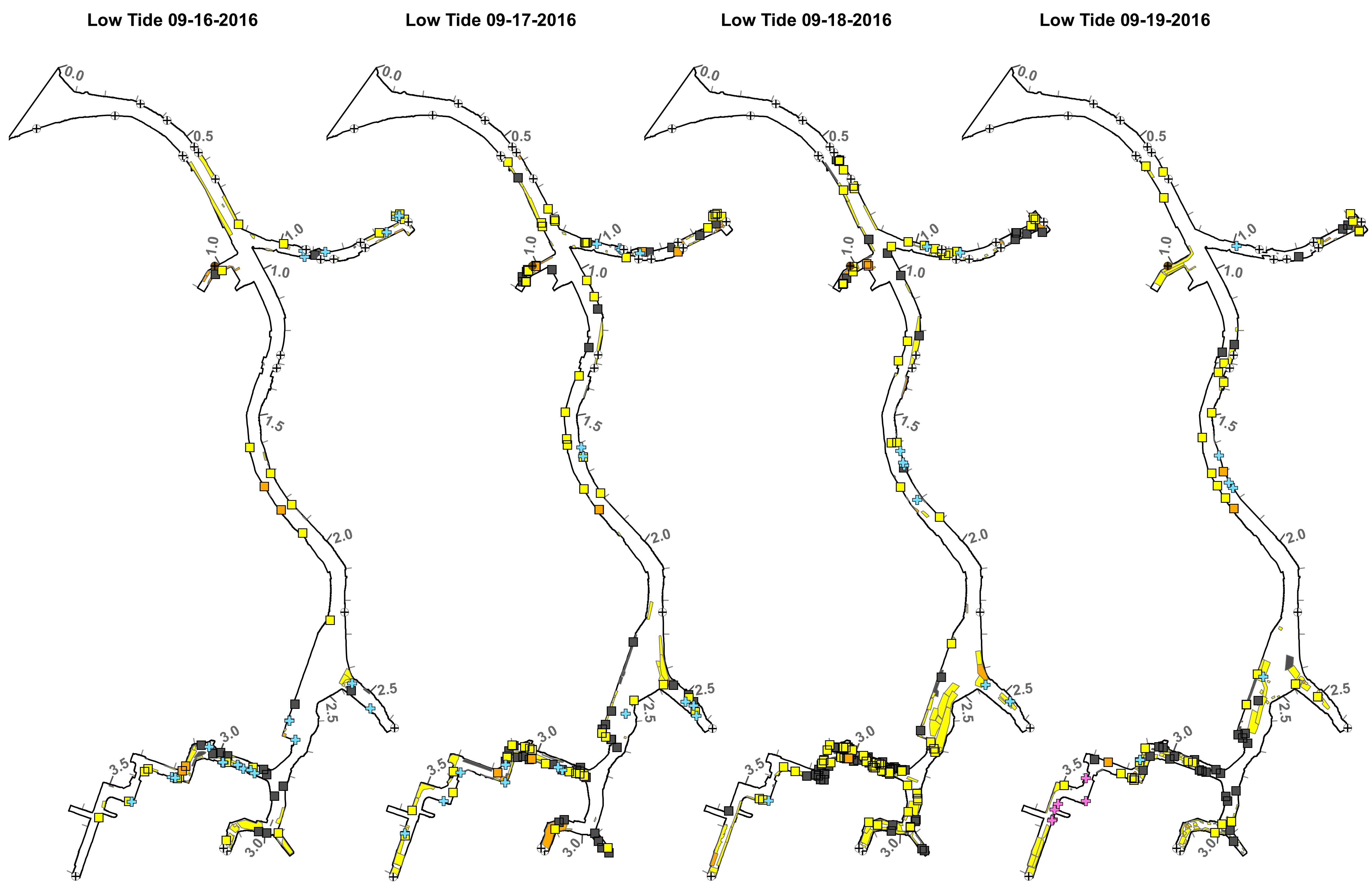

Newtown Creek Study Area
WWTP Treated Effluent Overflow
Combined Sewer Overflow
Bubbles Likely Associated with
Bubbles Likely Associated with Aeration System

Gas Bubble Frequency

Trace-low
Low-moderate
Moderate-high

Notes:
1. Base data acquired from New York City Department of Information Technology and Telecommunications.
2. Creek mile hatches are shown every tenth mile and labeled every half mile.
3. The spatial extent of apparent gas ebullition observations are shown as polygons; apparent gas ebullition observations smaller than 300 square feet in size are shown as filled square points instead of actual areas.
4. Rainfall occurred in the hours leading up to, and during the first half of, the 2016 Low Tide Survey No. 4.
5. WWTP: Wastewater Treatment Plant

Gas Ebullition Frequency:
i. Moderate-high frequency – bubbles are observed continuously or nearly continuously with regard to time within the area apparent gas ebullition is observed.
ii. Low-moderate frequency – bubbles appear intermittently and/or irregularly with regard to time within the area apparent gas ebullition is observed.
iii. Trace-low frequency – bubbles appear but less frequently than low-moderate with regard to time within the area apparent gas ebullition is observed.

0 750 1,500 2,250 Feet

\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_Ebullition\AQ_RI_AppndxD_FigD4_4b_EbullitionFrequency2016.mxd joliver 6/8/2020 5:12:41 PM

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Figure D4-4b
Apparent Gas Ebullition Observations by Gas Bubble Frequency – 2016
Gas Ebullition Evaluation
Newtown Creek RI/FS

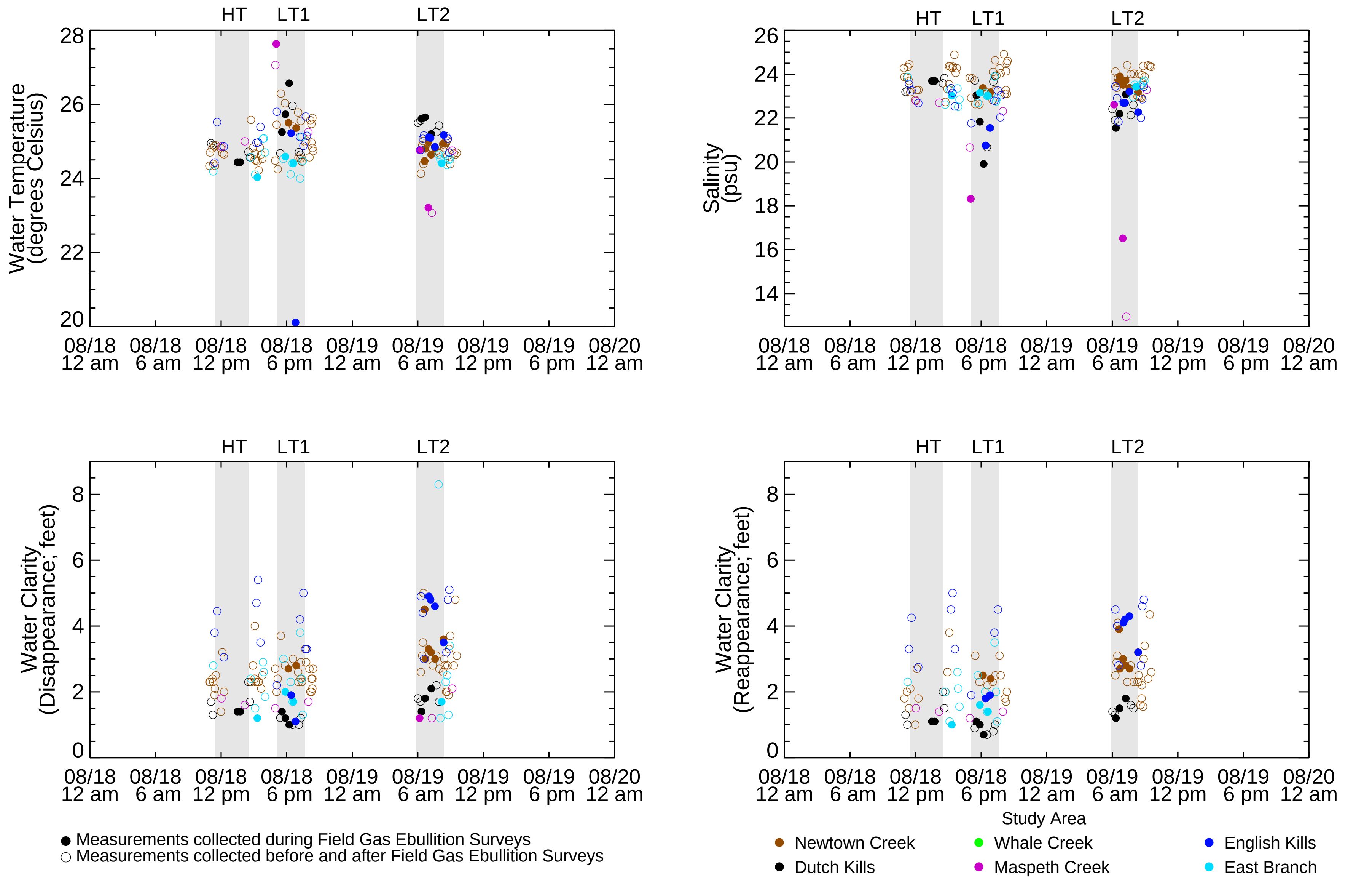

Figure D4-5a

Surface Water Quality Measurements - 2015
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Shaded areas indicate time of surveys.
One water temperature measurement was treated as an extreme outlier due to a measurement error and removed from the analysis.
HT: High Tide Survey No. 1; LT1: Low Tide Survey No. 1; LT2: Low Tide Survey No. 2

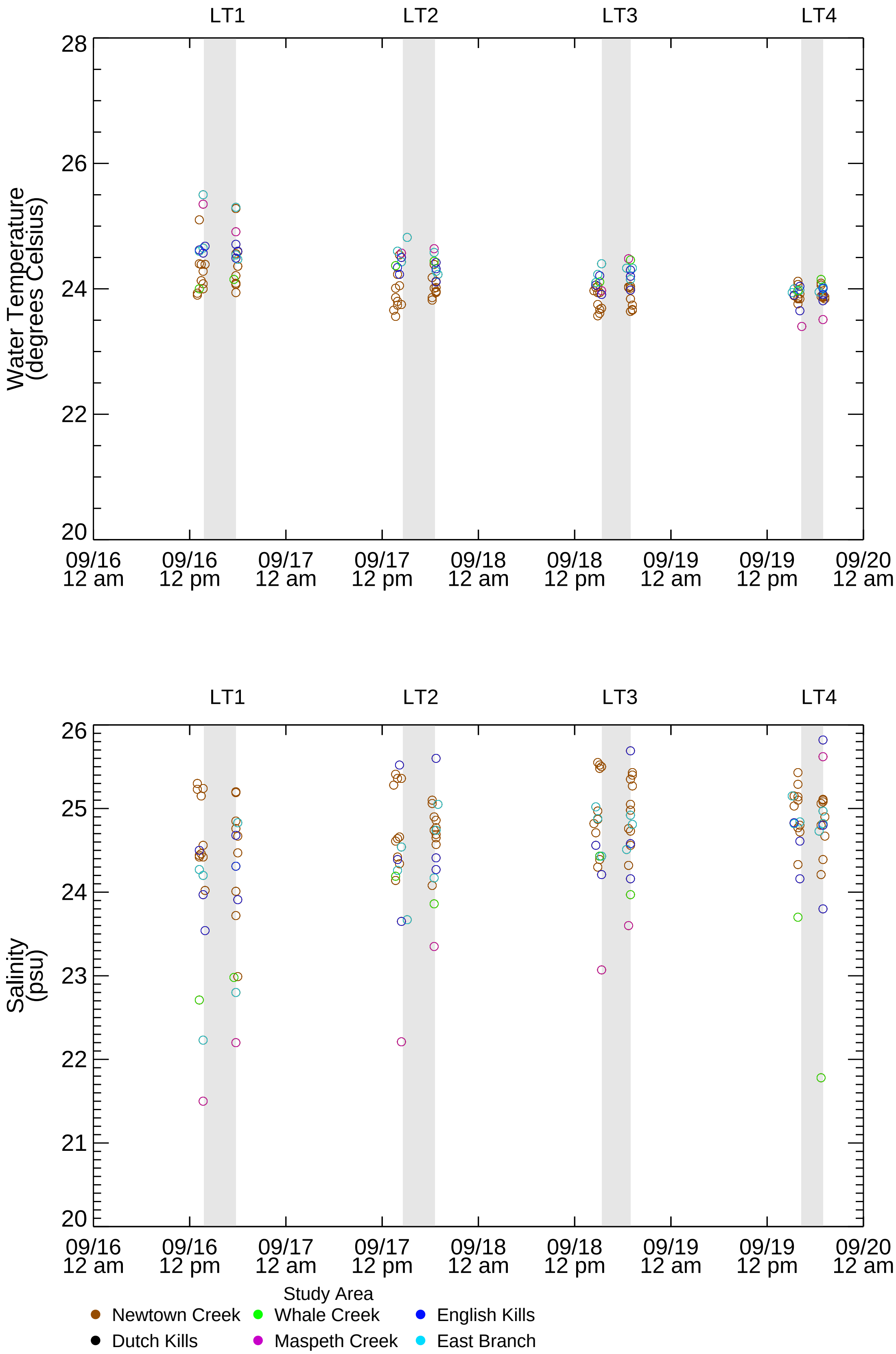

Figure D4-5b

Surface Water Quality Measurements - 2016
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Shaded areas indicate time of field gas ebullition surveys. Surface water quality measurements collected before and after surveys. One salinity measurement was treated as an extreme outlier due to measurement error and removed from analysis. LT1: Low Tide Survey No. 1; LT2: Low Tide Survey No. 2; LT3: Low Tide Survey No. 3; LT4: Low Tide Survey No. 4

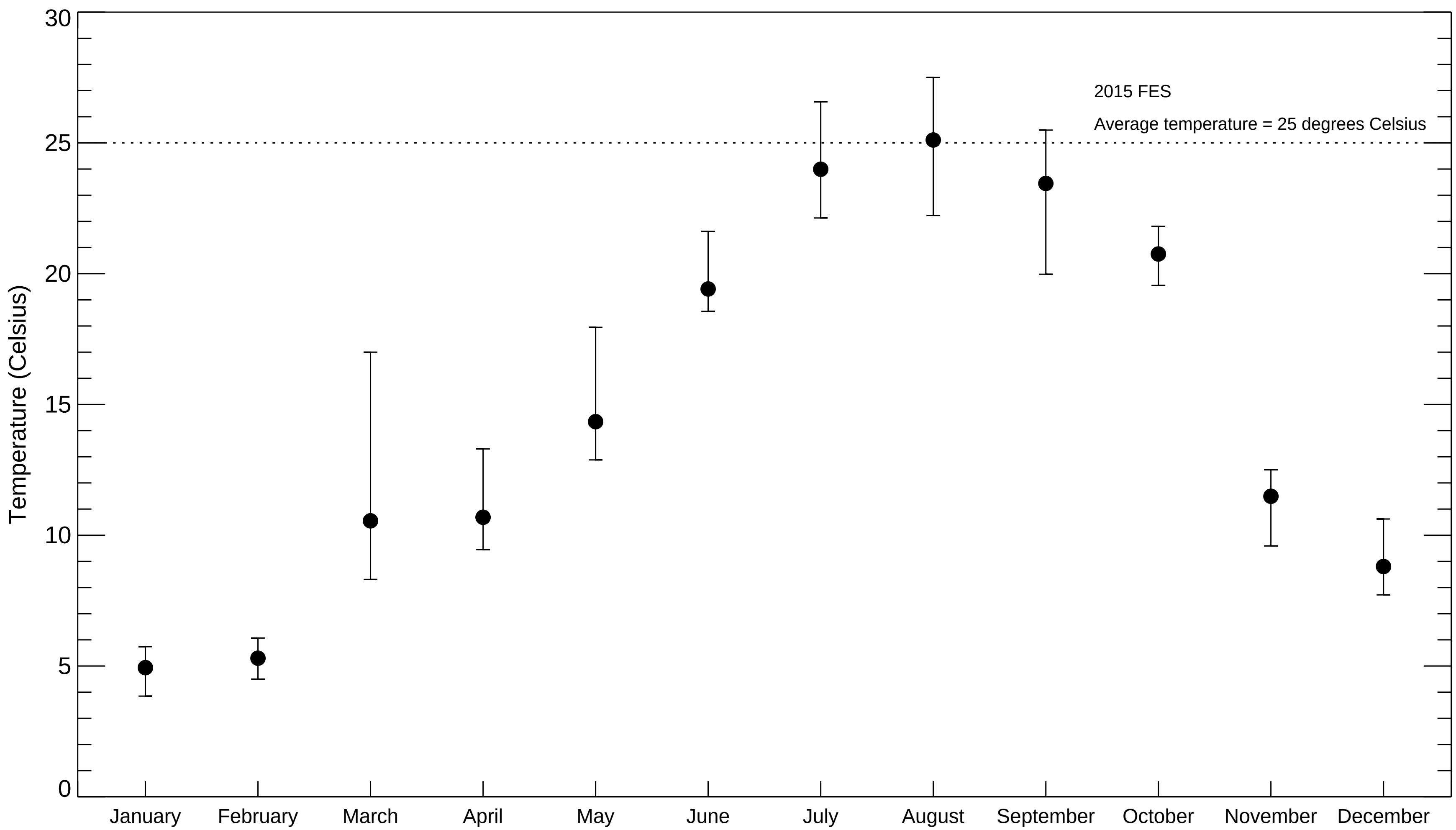

Figure D4-6a

Monthly Surface Water Temperatures - 2015 FES
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Average surface water temperature from Phase 1 RI dry weather surface water sample results collected from Study Area. Error bars are the maximum and minimum surface water temperatures measured during sampling.

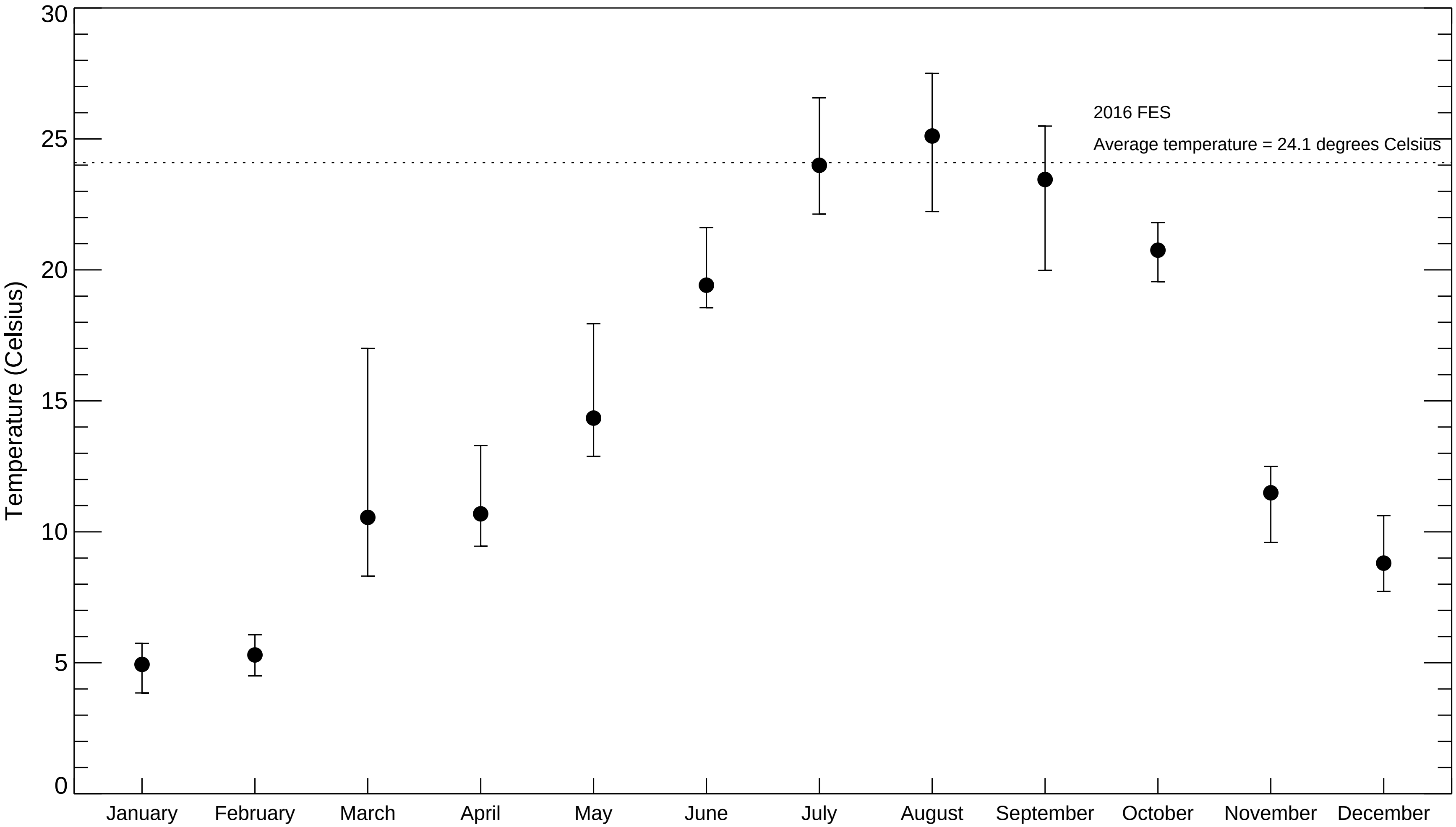

Figure D4-6b

Monthly Surface Water Temperatures - 2016 FES
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Average surface water temperature from Phase 1 RI dry weather surface water sample results collected from Study Area. Error bars are the maximum and minimum surface water temperatures measured during sampling.

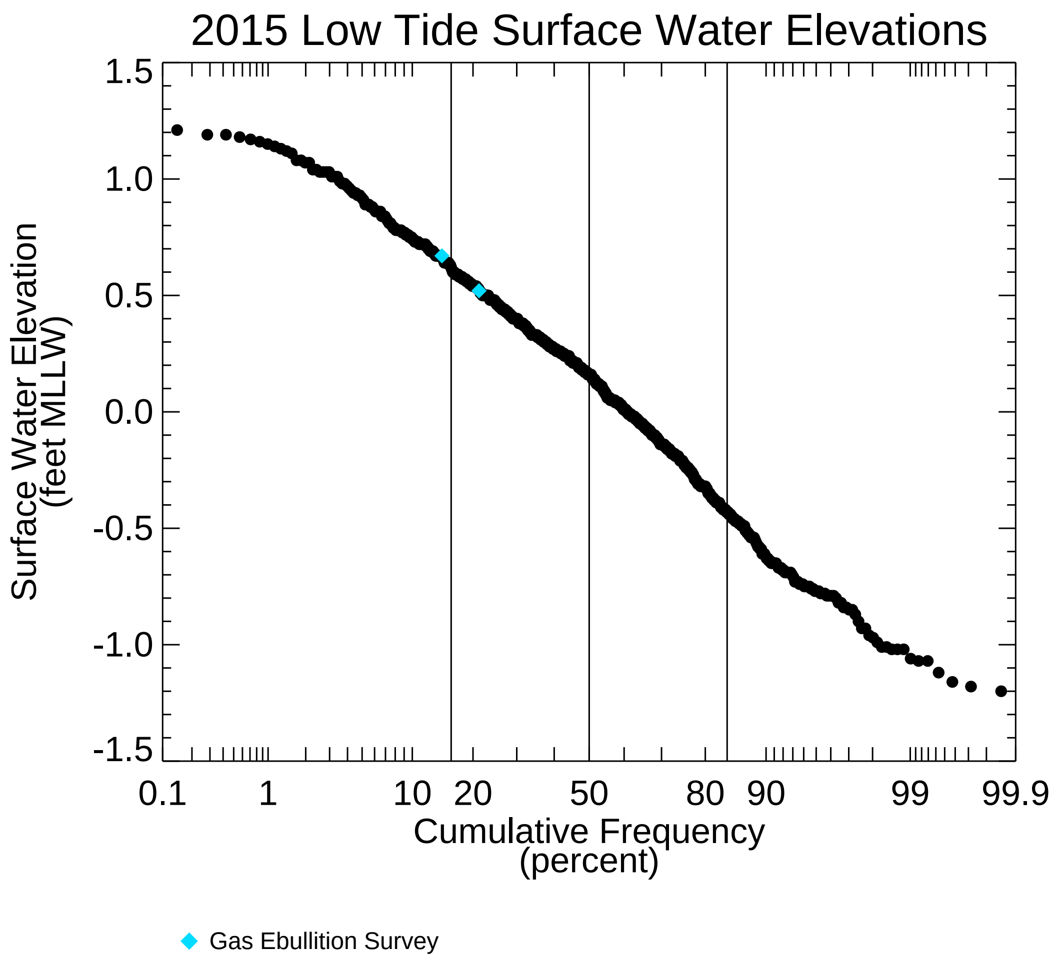

Figure D4-7a

Low Tide Surface Water Elevations - 2015
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Estimated tidal elevation data, referenced to the mean lower low water (MLLW) tidal datum, obtained from National Oceanic and Atmospheric Administration (NOAA) for Hunters Point, Newtown Creek, NY.

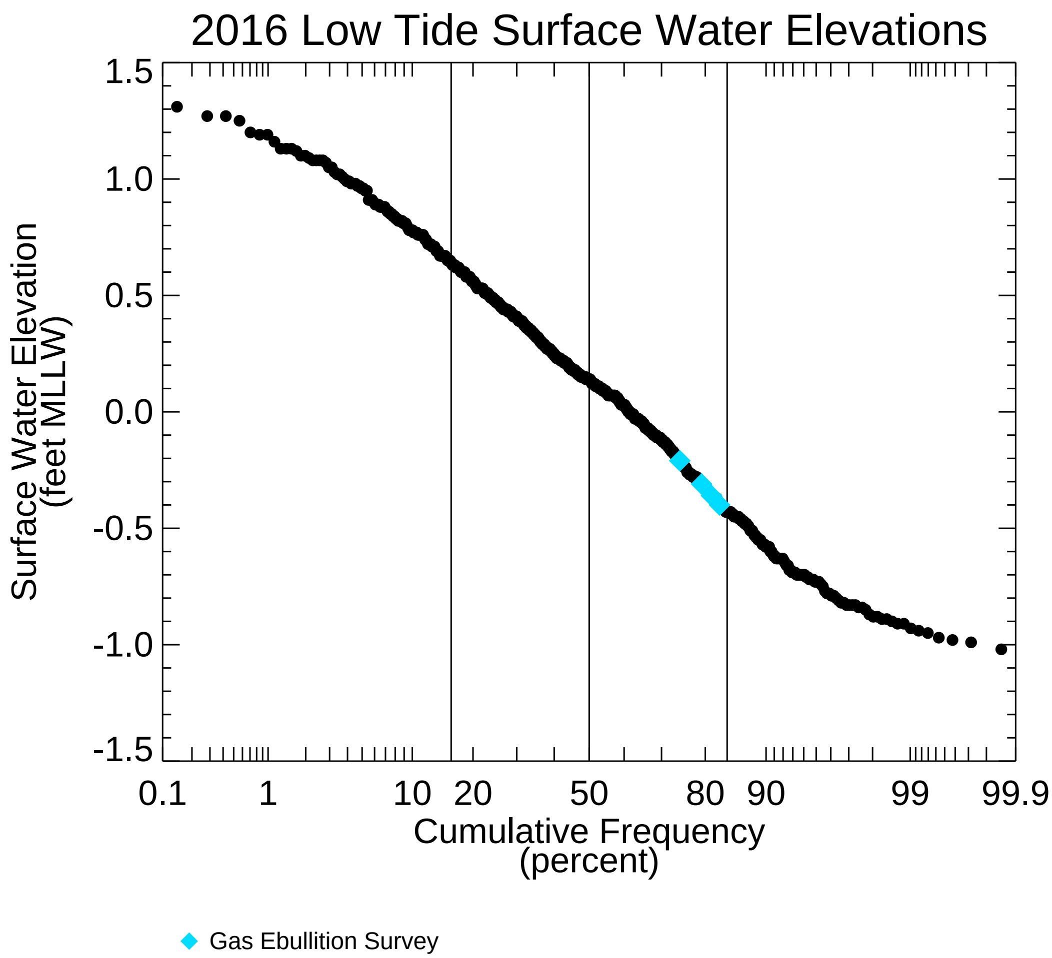

Figure D4-7b

Low Tide Surface Water Elevations - 2016
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Estimated tidal elevation data, referenced to the mean lower low water (MLLW) tidal datum, obtained from National Oceanic and Atmospheric Administration (NOAA) for Hunters Point, Newtown Creek, NY.

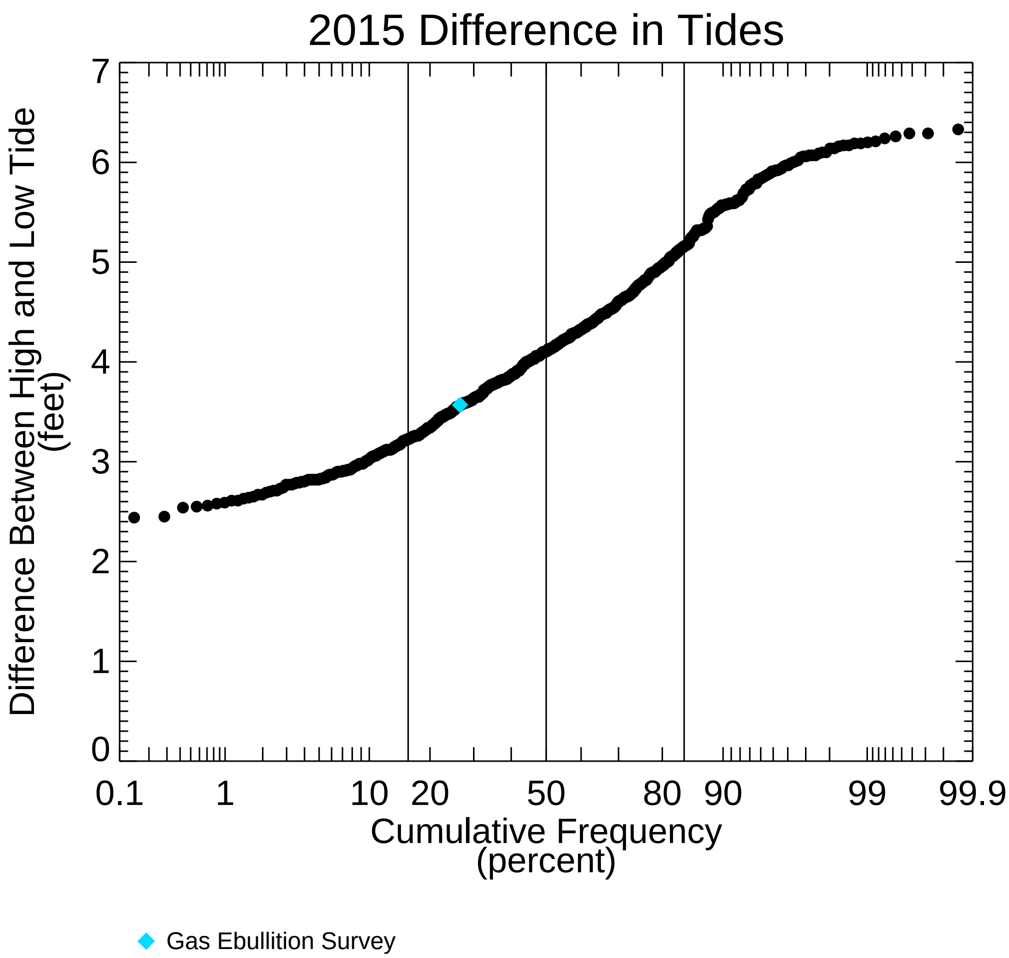

Figure D4-8a

Differences Between High and Low Tides - 2015
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Estimated tidal elevation data, referenced to the mean lower low water (MLLW) tidal datum, obtained from National Oceanic and Atmospheric Administration (NOAA) for Hunters Point, Newtown Creek, NY.

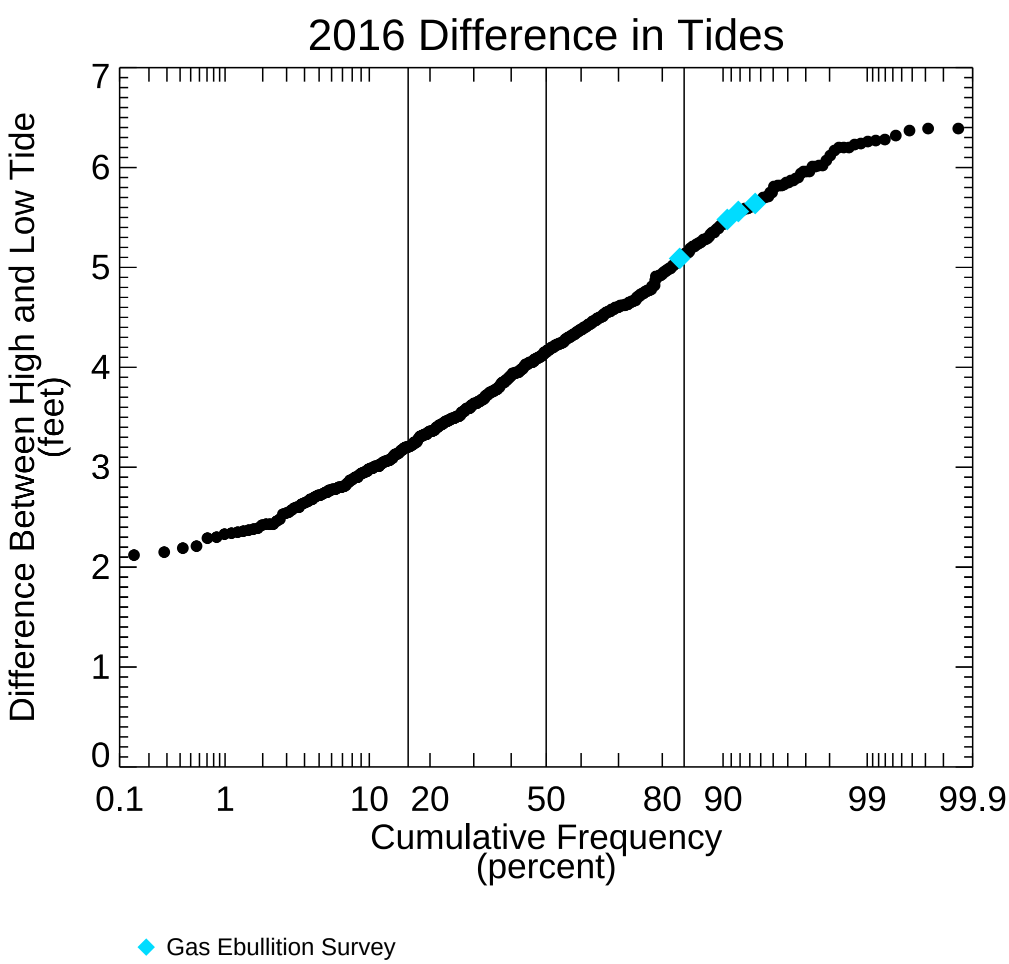

Figure D4-8b

Differences Between High and Low Tides - 2016
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Estimated tidal elevation data, referenced to the mean lower low water (MLLW) tidal datum, obtained from National Oceanic and Atmospheric Administration (NOAA) for Hunters Point, Newtown Creek, NY.

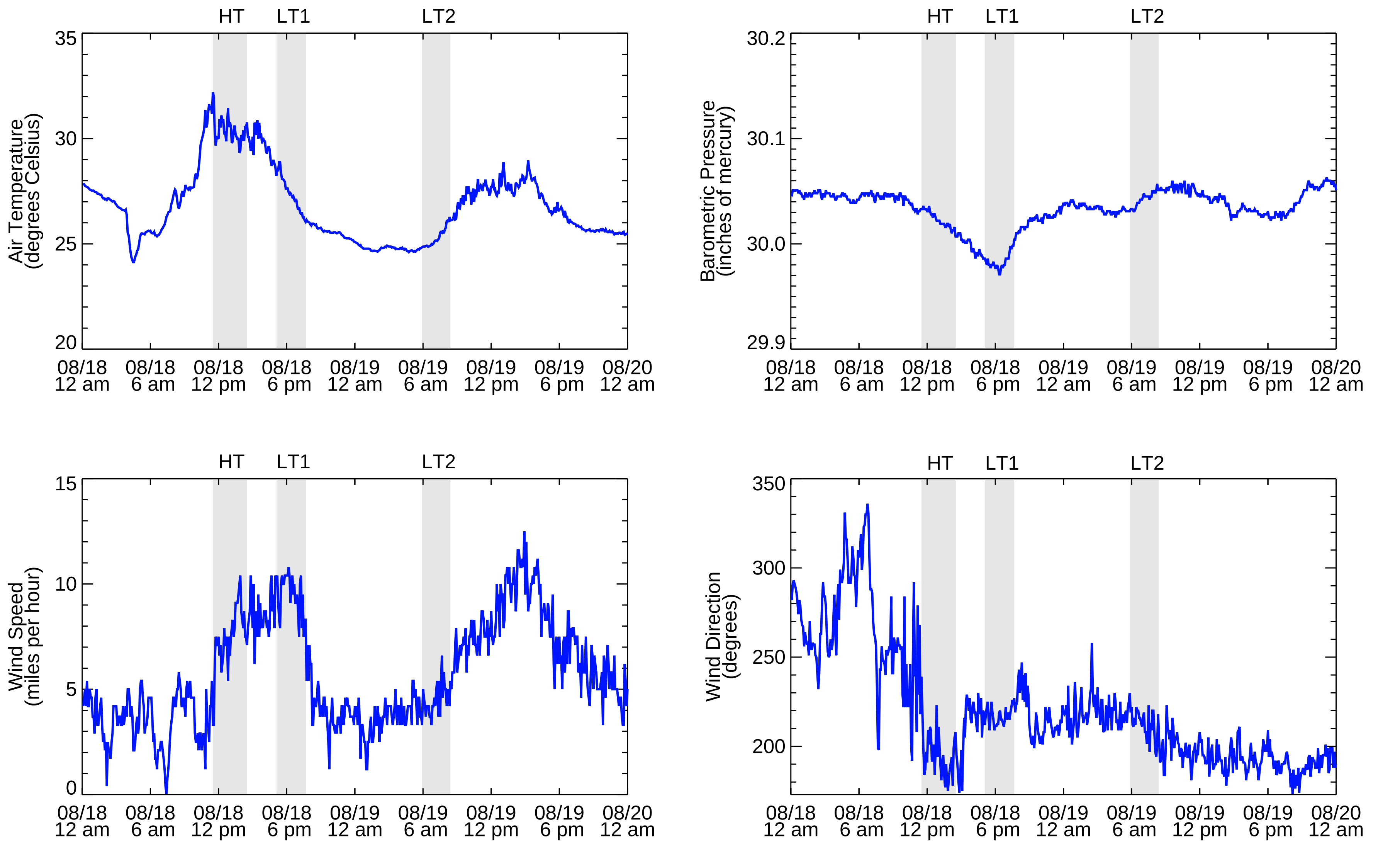

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Figure D4-9a

Weather Conditions - 2015
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Data obtained from Greenpoint Energy Center weather station.
Barometric pressure: 1 bar = 29.61 inches of mercury (at 16 degrees Celsius). Shaded areas indicate time of surveys.
HT: High Tide Survey No. 1; LT1: Low Tide Survey No. 1; LT2: Low Tide Survey No. 2

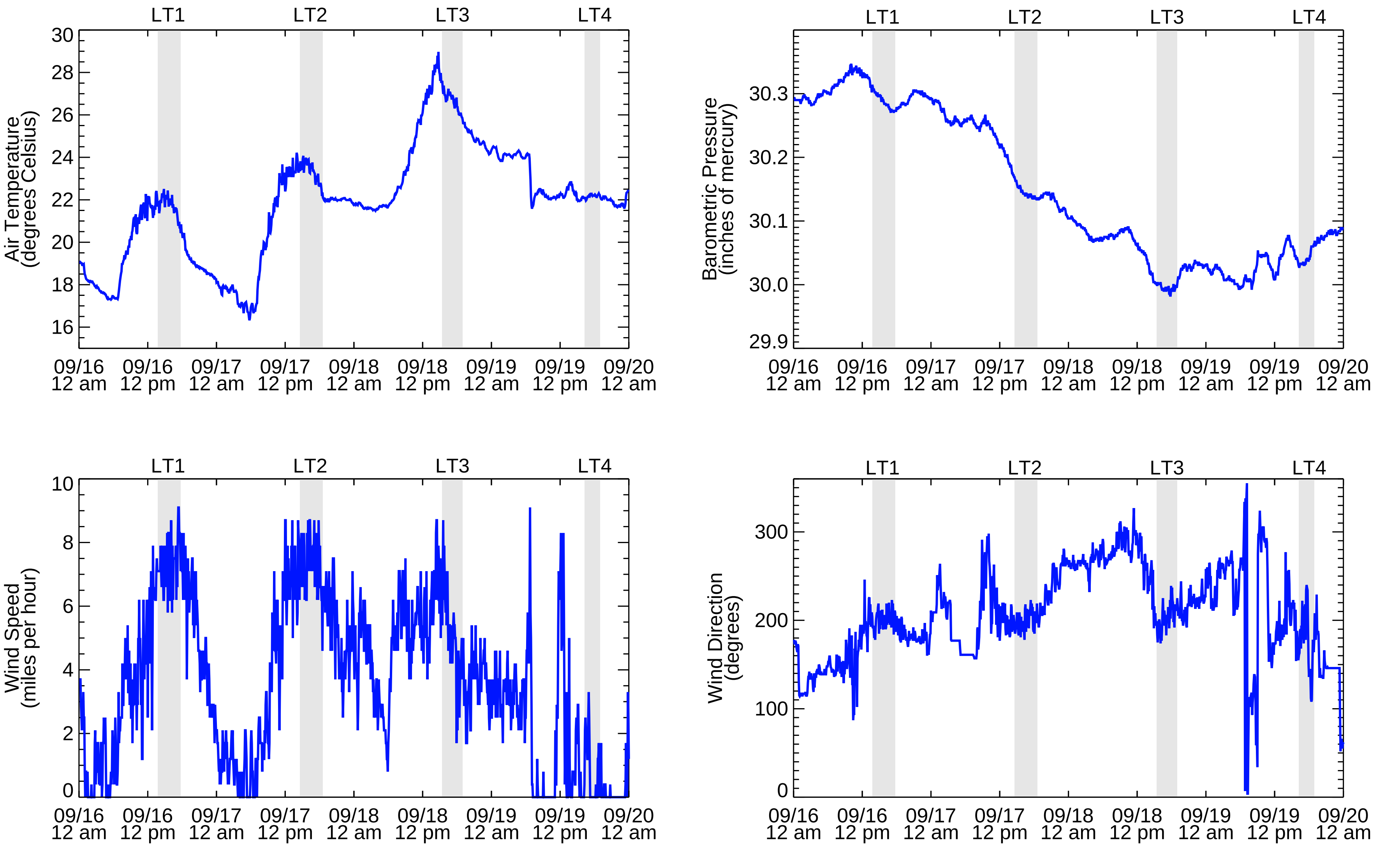

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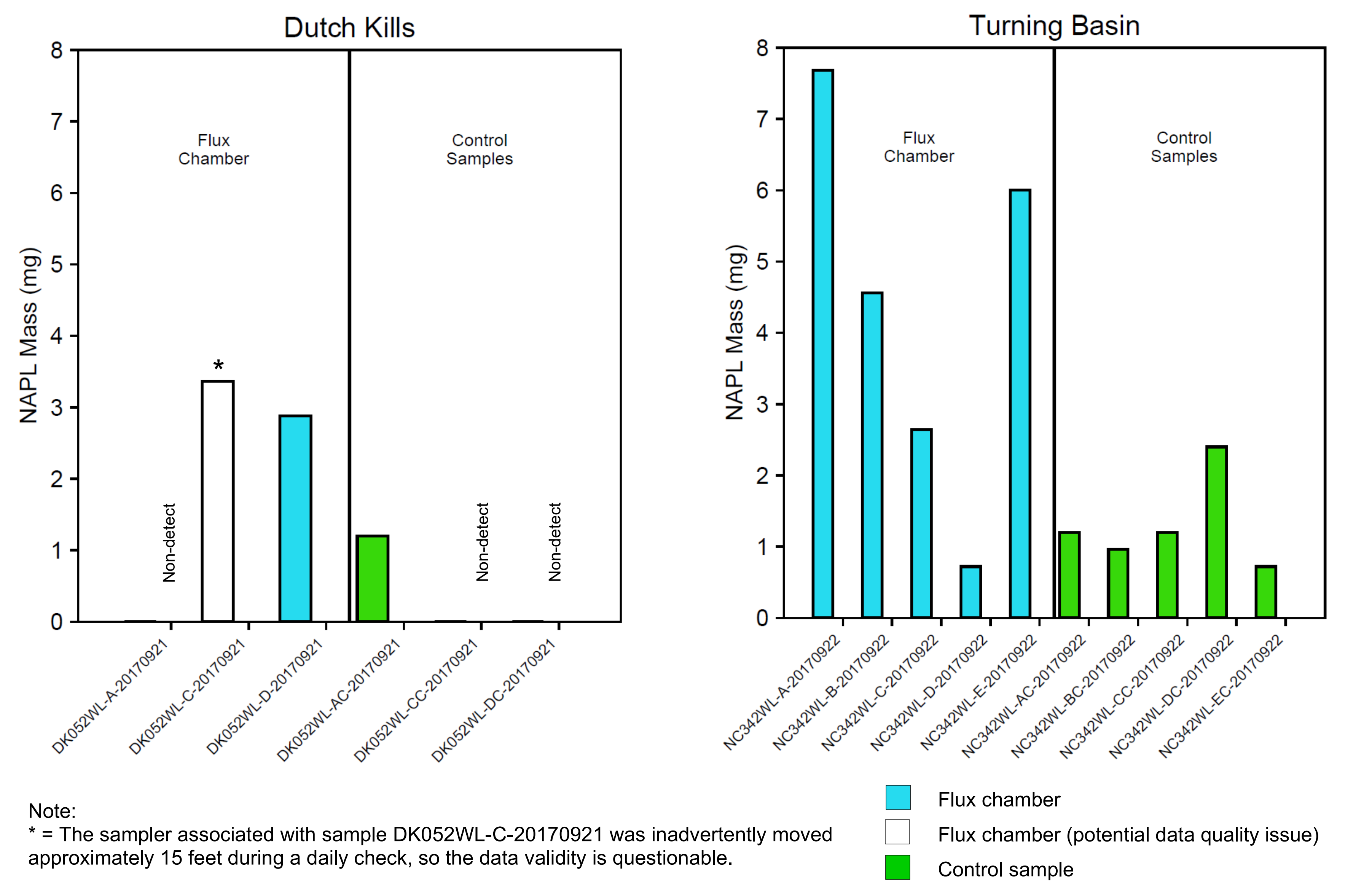
Figure D4-9b

Weather Conditions - 2016
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Data obtained from Greenpoint Energy Center weather station.
Barometric pressure: 1 bar = 29.61 inches of mercury (at 16 degrees Celsius). Shaded areas indicate time of surveys.
LT1: Low Tide Survey No. 1; LT2: Low Tide Survey No. 2; LT3: Low Tide Survey No. 3; LT4: Low Tide Survey No. 4



Note:
* = The sampler associated with sample DK052WL-C-20170921 was inadvertently moved approximately 15 feet during a daily check, so the data validity is questionable.

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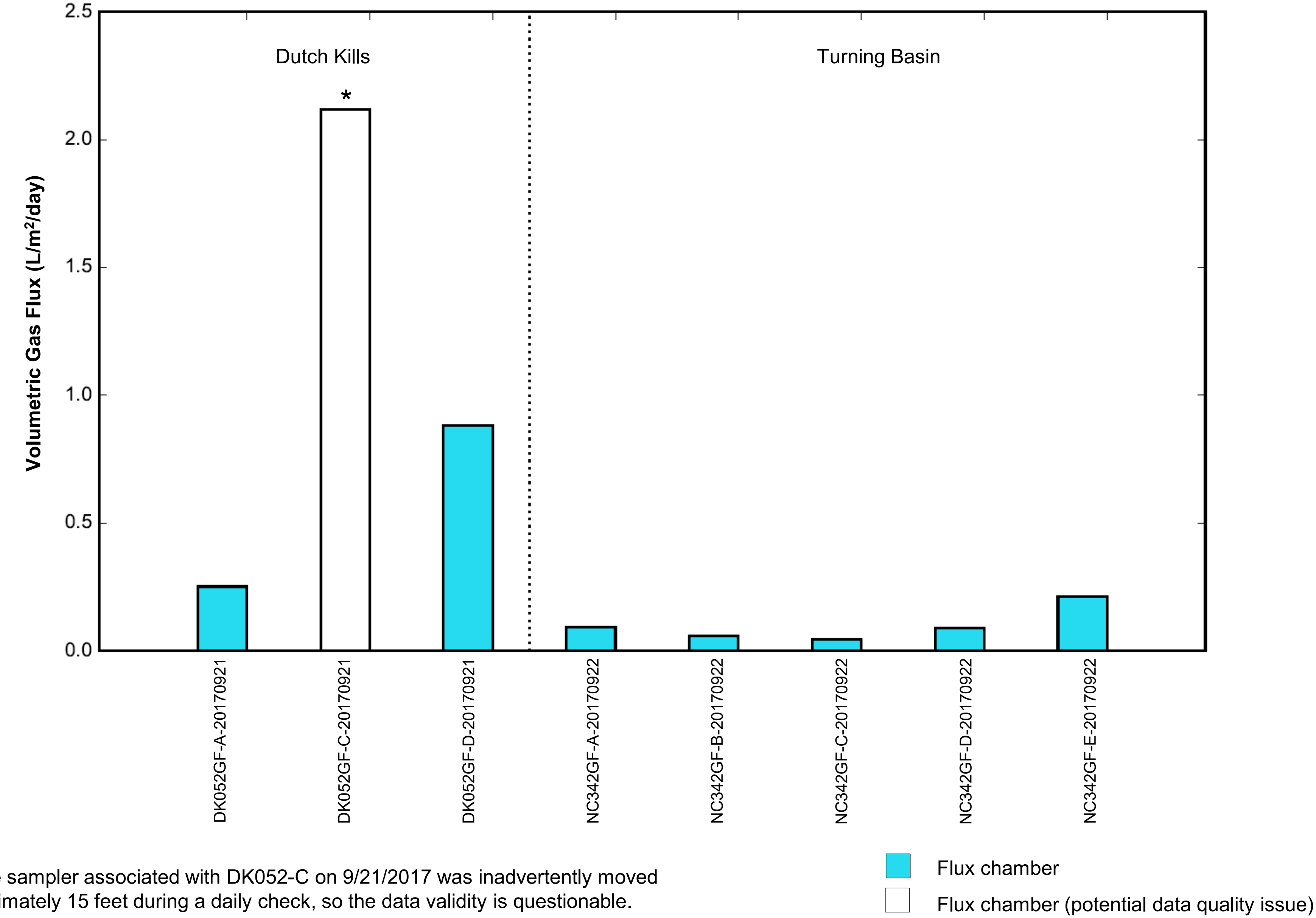
Figure D4-10
Pilot Study Flux Chamber NAPL Mass – 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS



Note:
* = The sampler associated with DK052-C on 9/21/2017 was inadvertently moved approximately 15 feet during a daily check, so the data validity is questionable.

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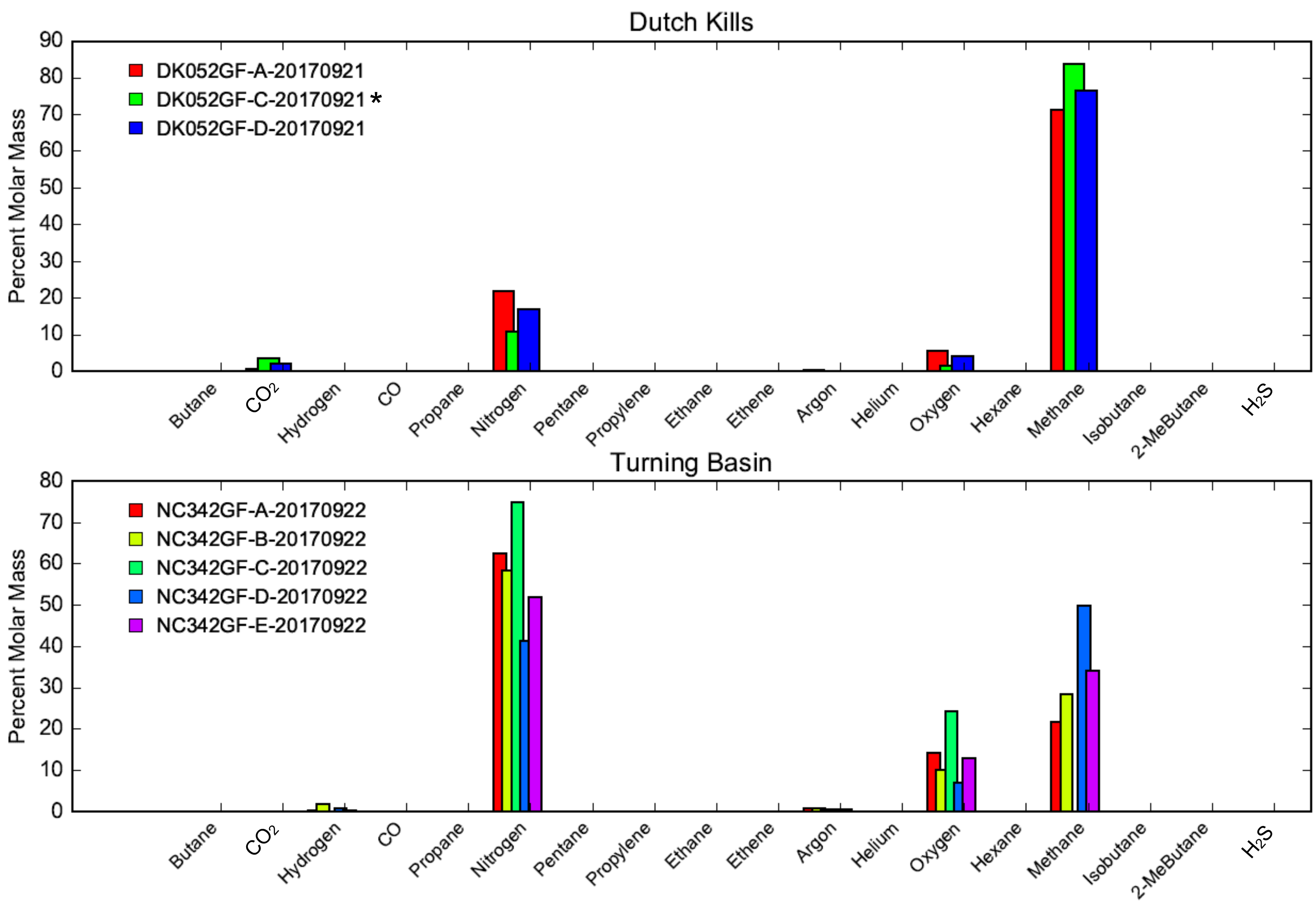
Figure D4-11
Pilot Study Flux Chamber Volumetric Gas Flux – 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS



Notes:
Ambient air correction and H_2S concentration added to percent molar mass.
* = The sampler associated with DK052-C on 9/21/2017 was inadvertently moved approximately 15 feet during a daily check, so the data validity is questionable.

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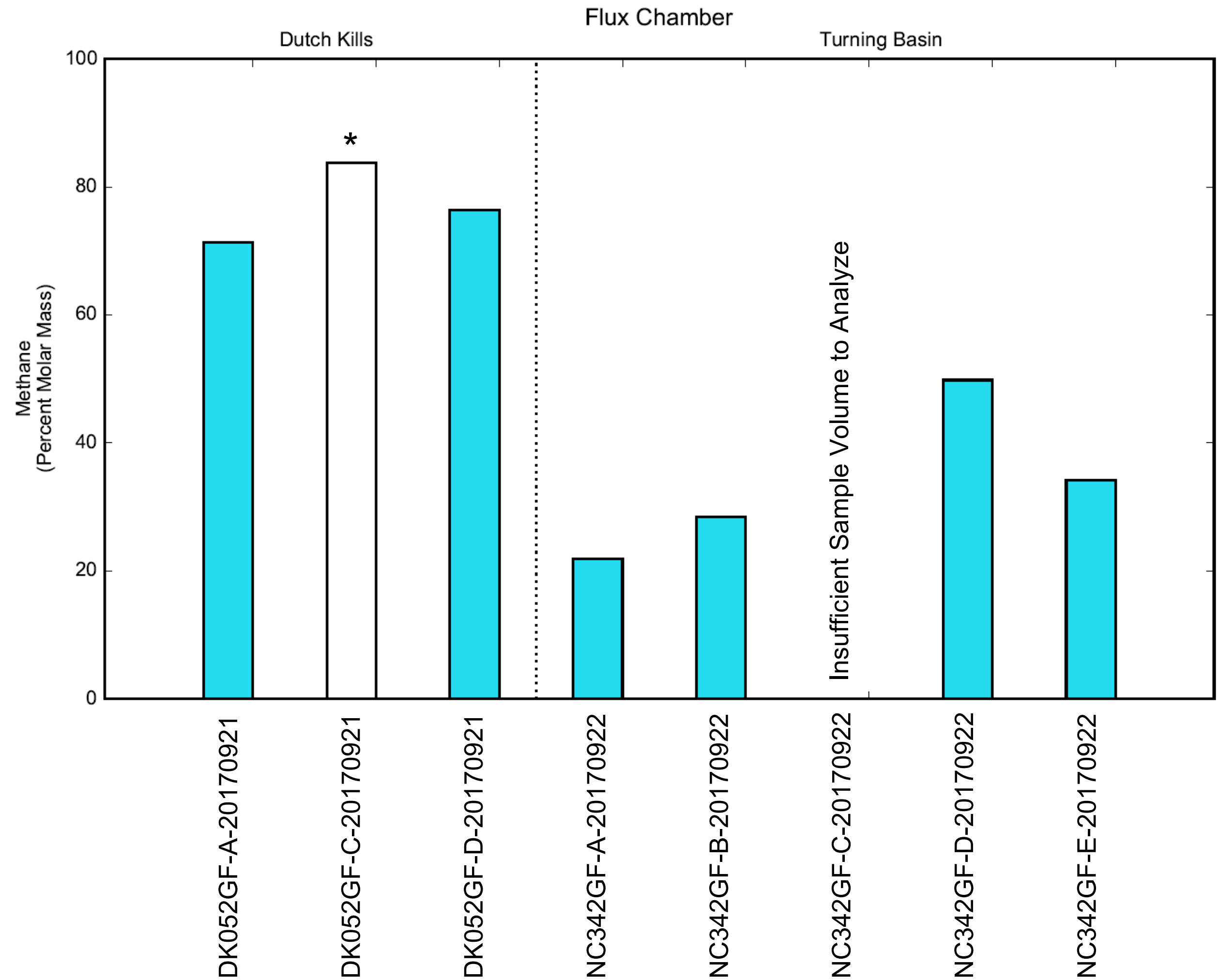
Figure D4-12a
Pilot Study Flux Chamber Gas Composition – 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS

0



Notes:
Ambient air correction and H_2S concentration added to calculate percent molar mass for all analyzed gases.
* = The sampler associated with DK052-C on 9/21/2017 was inadvertently moved approximately 15 feet during a daily check, so the data validity is questionable.

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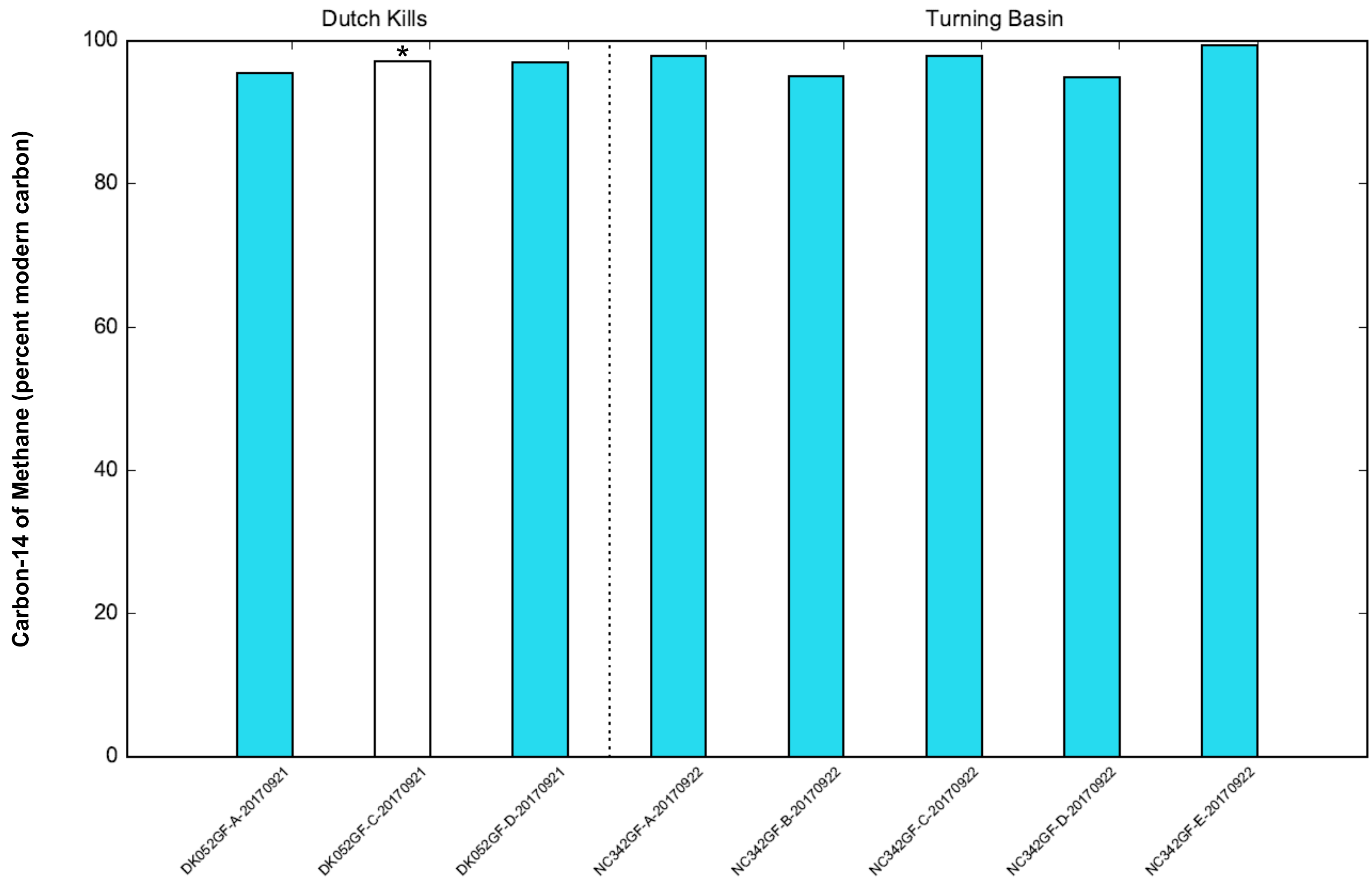
Figure D4-12b
Pilot Study Flux Chamber Methane Content Results – 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS



Note:
* = The sampler associated with DK052GF-C on 9/21/2017 was inadvertently moved approximately 15 feet during a daily check, so the data validity is questionable.

Flux chamber
Flux chamber (potential data quality issue)

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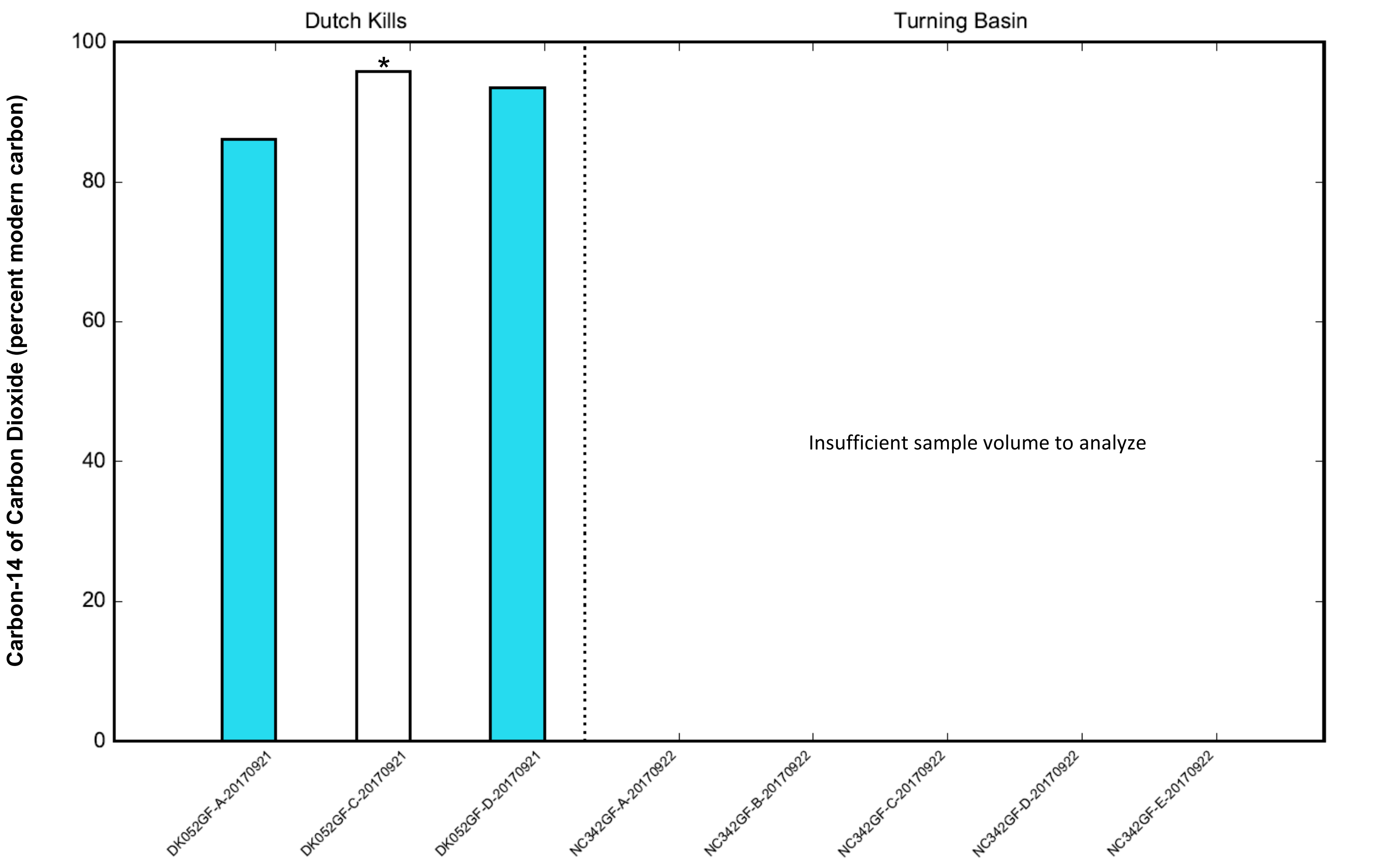
Figure D4-13
Pilot Study Flux Chamber Carbon-14 Results of Methane – 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS



Note:
* = The sampler associated with DK052GF-C on 9/21/2017 was inadvertently moved approximately 15 feet during a daily check, so the data validity is questionable.

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Figure D4-14
Pilot Study Flux Chamber Carbon-14 Results of Carbon Dioxide – 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS

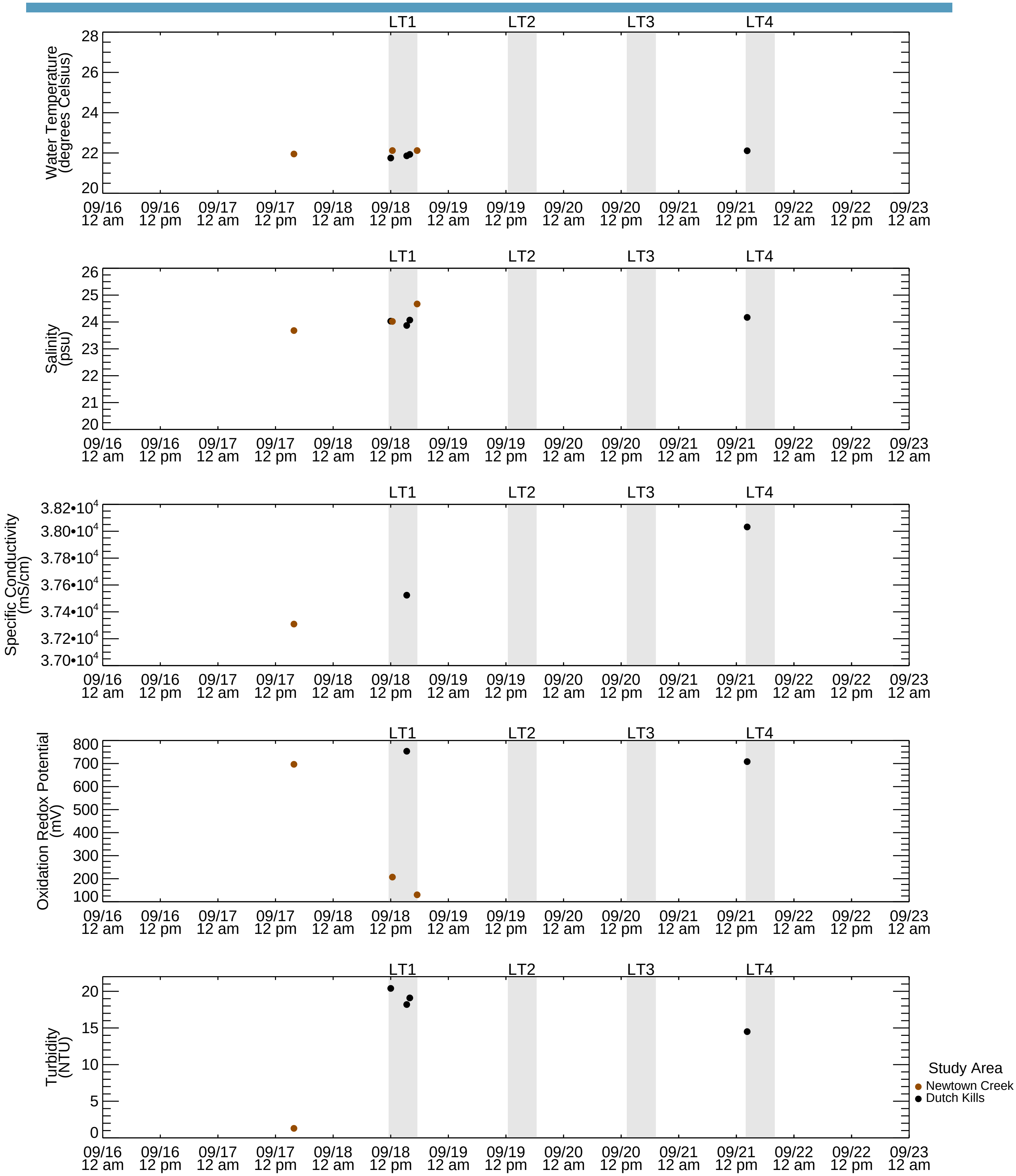

Figure D4-15

Surface Water Quality Measurements - 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Shaded areas indicate time of field gas ebullition surveys.
Water quality measurements collected before and after field gas ebullition surveys.
LT1: Low Tide Survey No. 1; LT2: Low Tide Survey No. 2; LT3: Low Tide Survey No. 3; LT4: Low Tide Survey No. 4

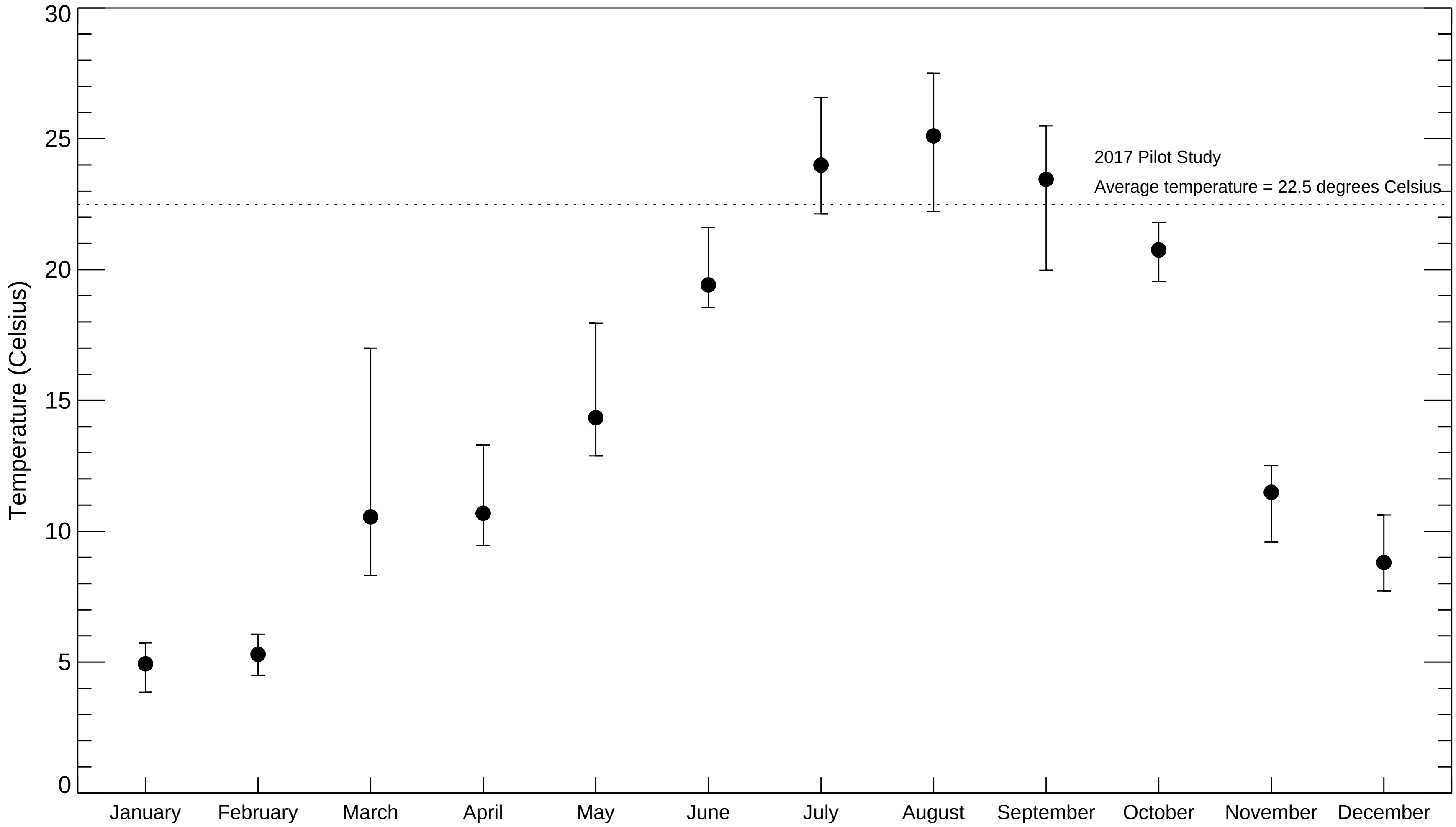

Figure D4-16
Monthly Surface Water Temperatures - 2017 Pilot Study
Gas Ebullition Evaluation
Newtown Creek RI/FS

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Notes: Average surface water temperature from Phase 1 RI dry weather surface water sample results collected from Study Area. Error bars are the maximum and minimum surface water temperatures measured during sampling.

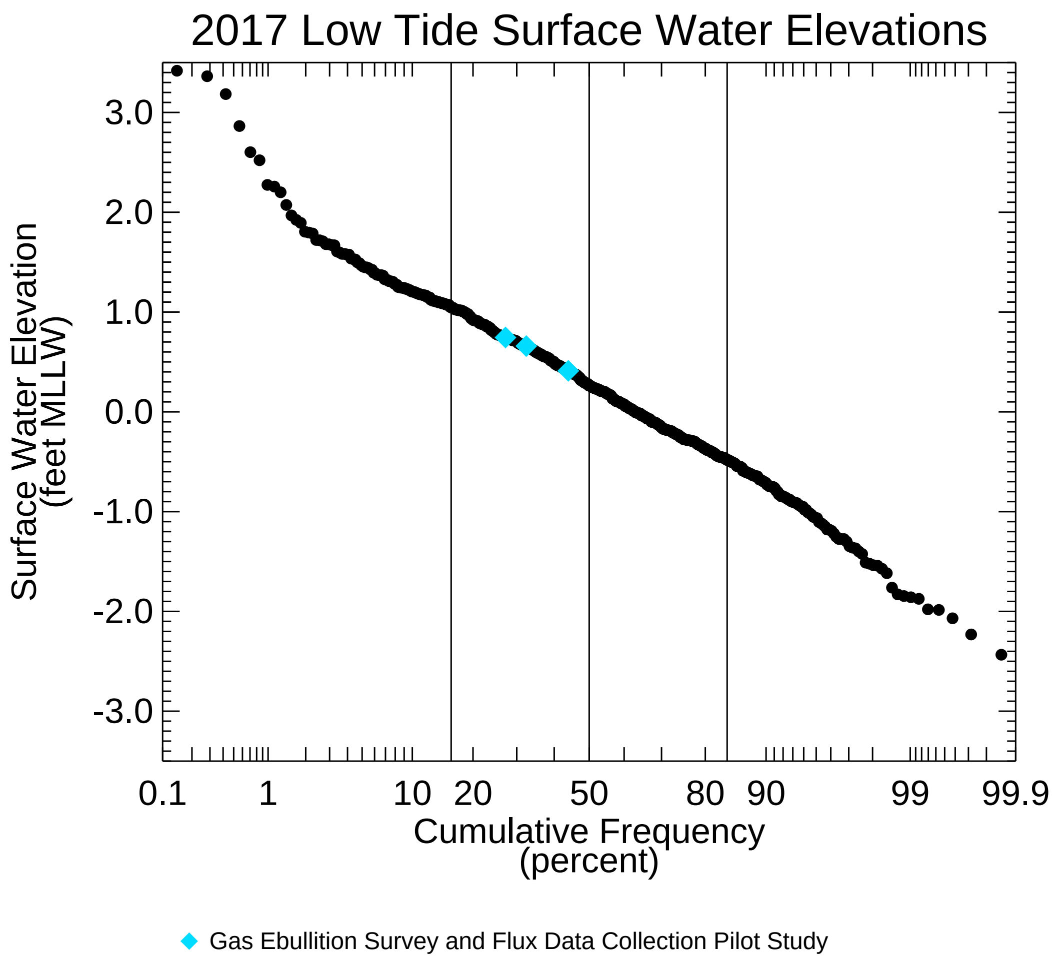

Figure D4-17

Low Tide Surface Water Elevations - 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Estimated tidal elevation data, referenced to the mean lower low water (MLLW) tidal datum, obtained from National Oceanic and Atmospheric Administration (NOAA) for Hunters Point, Newtown Creek, NY.

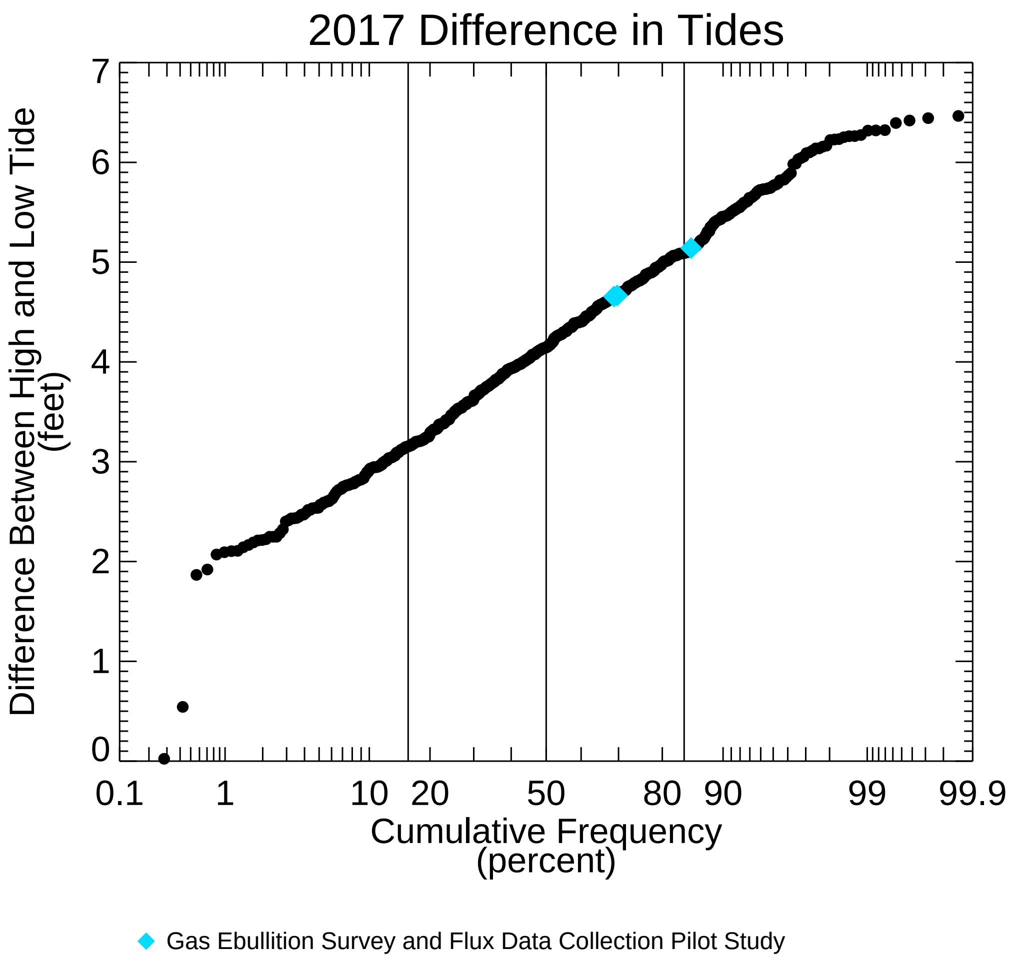

Figure D4-18

Differences Between High and Low Tides - 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Estimated tidal elevation data, referenced to the mean lower low water (MLLW) tidal datum, obtained from National Oceanic and Atmospheric Administration (NOAA) for Hunters Point, Newtown Creek, NY.

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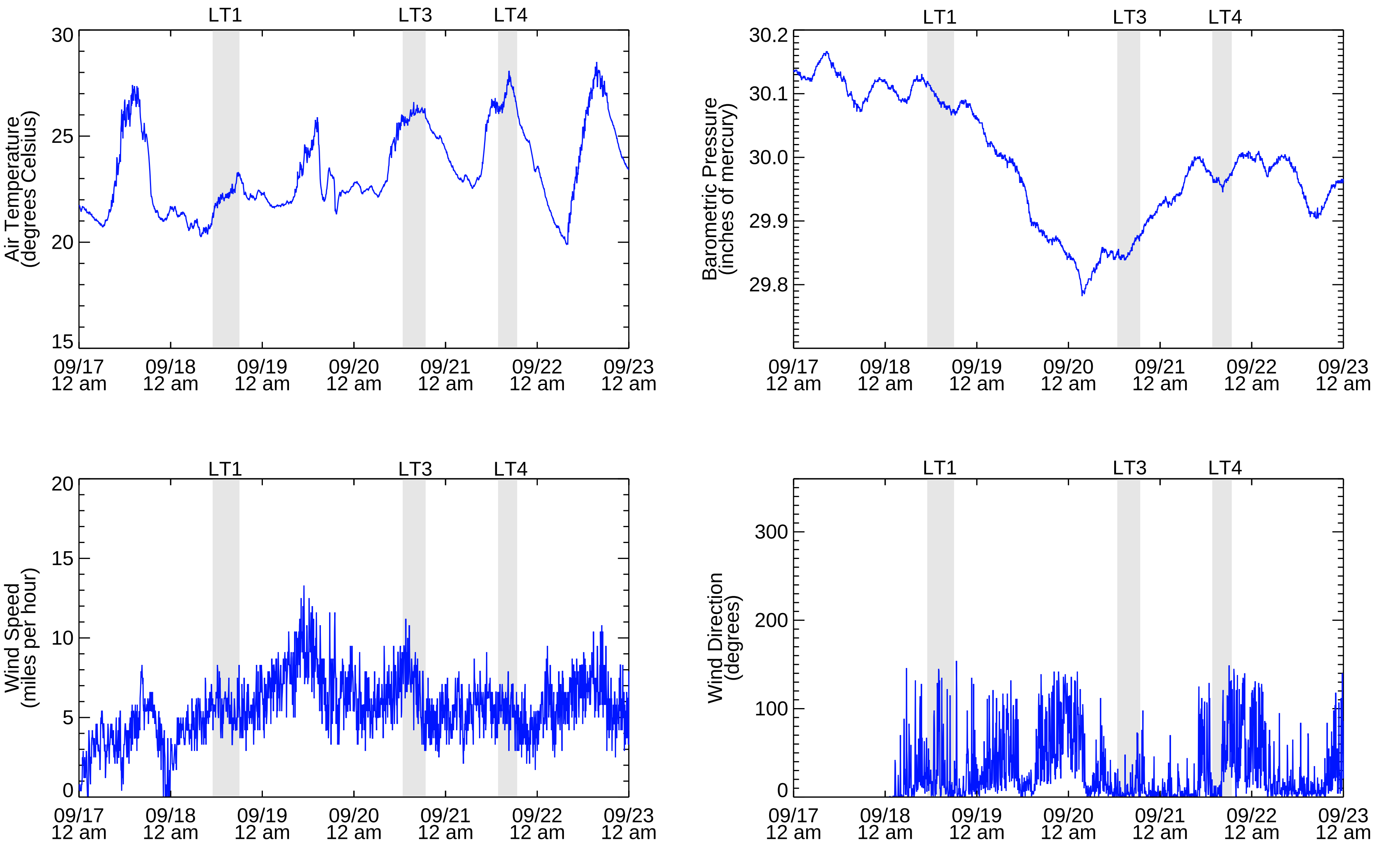

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Figure D4-19

Weather Conditions - 2017
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Data obtained from Field Facility weather station.
Barometric pressure: 1 bar = 29.61 inches of mercury (at 16 degrees Celsius). Shaded areas indicate time of surveys.
Low Tide Survey No. 2 was not conducted due to high winds and storm surge. LT1: Low Tide Survey No. 1; LT3: Low Tide Survey No. 3; LT4: Low Tide Survey No. 4

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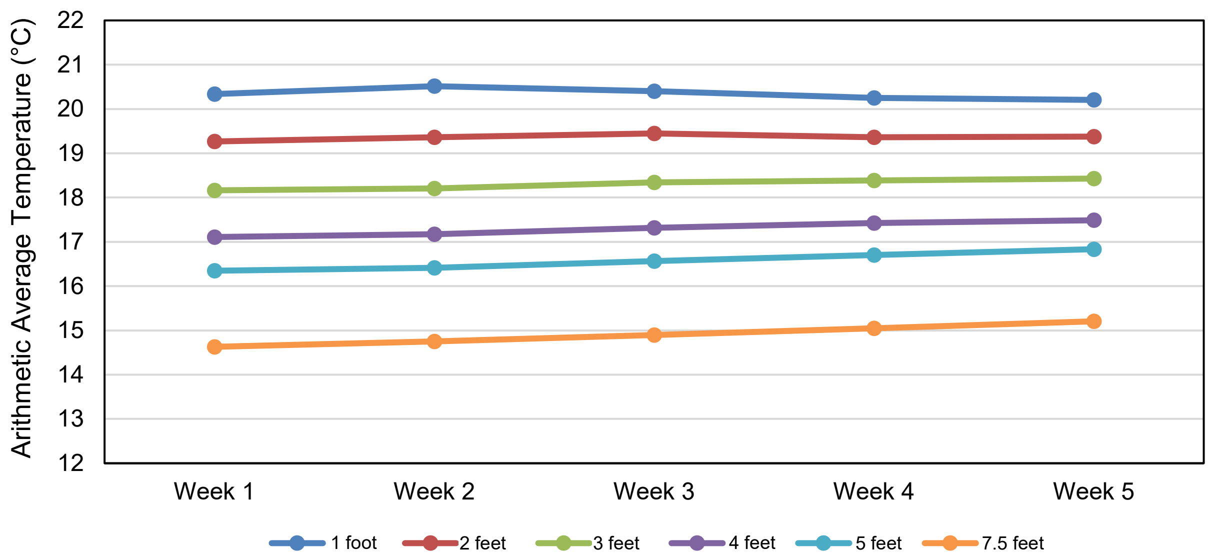
Dutch Kills (DK052)

Week 1 = 9/17/17 to 9/22/17
Week 2 = 9/23/17 to 9/29/17
Week 3 = 9/30/17 to 10/6/17
Week 4 = 10/7/17 to 10/13/17
Week 5 = 10/14/17 to 10/17/17

Note: No data at 10 feet due to sensor malfunction.



Turning Basin (NC342)

Week 1 = 9/16/17 to 9/22/17
Week 2 = 9/23/17 to 9/29/17
Week 3 = 9/30/17 to 10/6/17
Week 4 = 10/7/17 to 10/13/17
Week 5 = 10/14/17 to 10/17/17

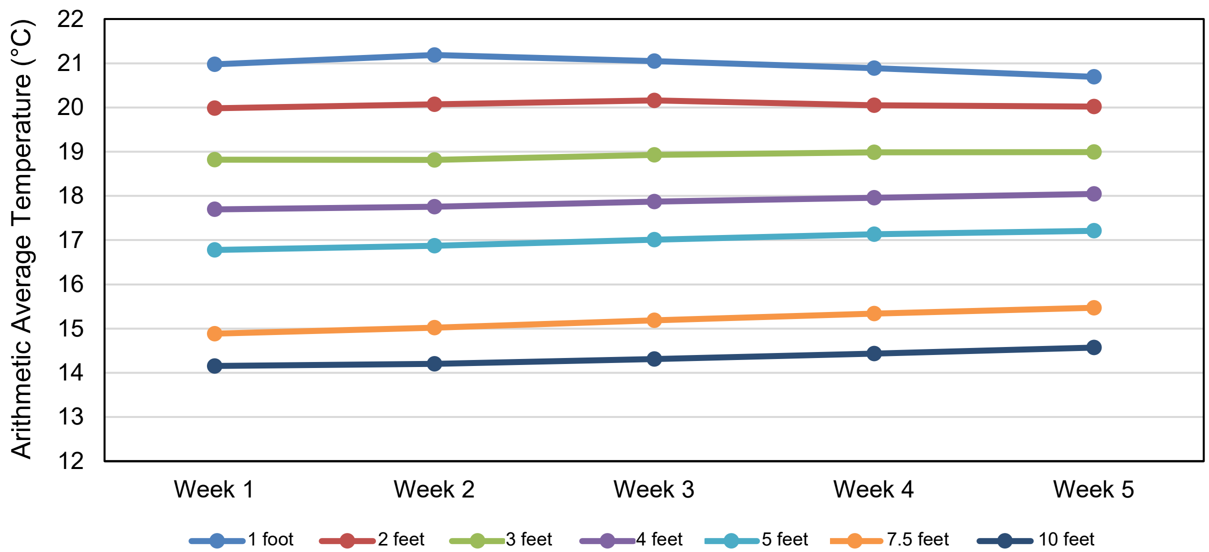


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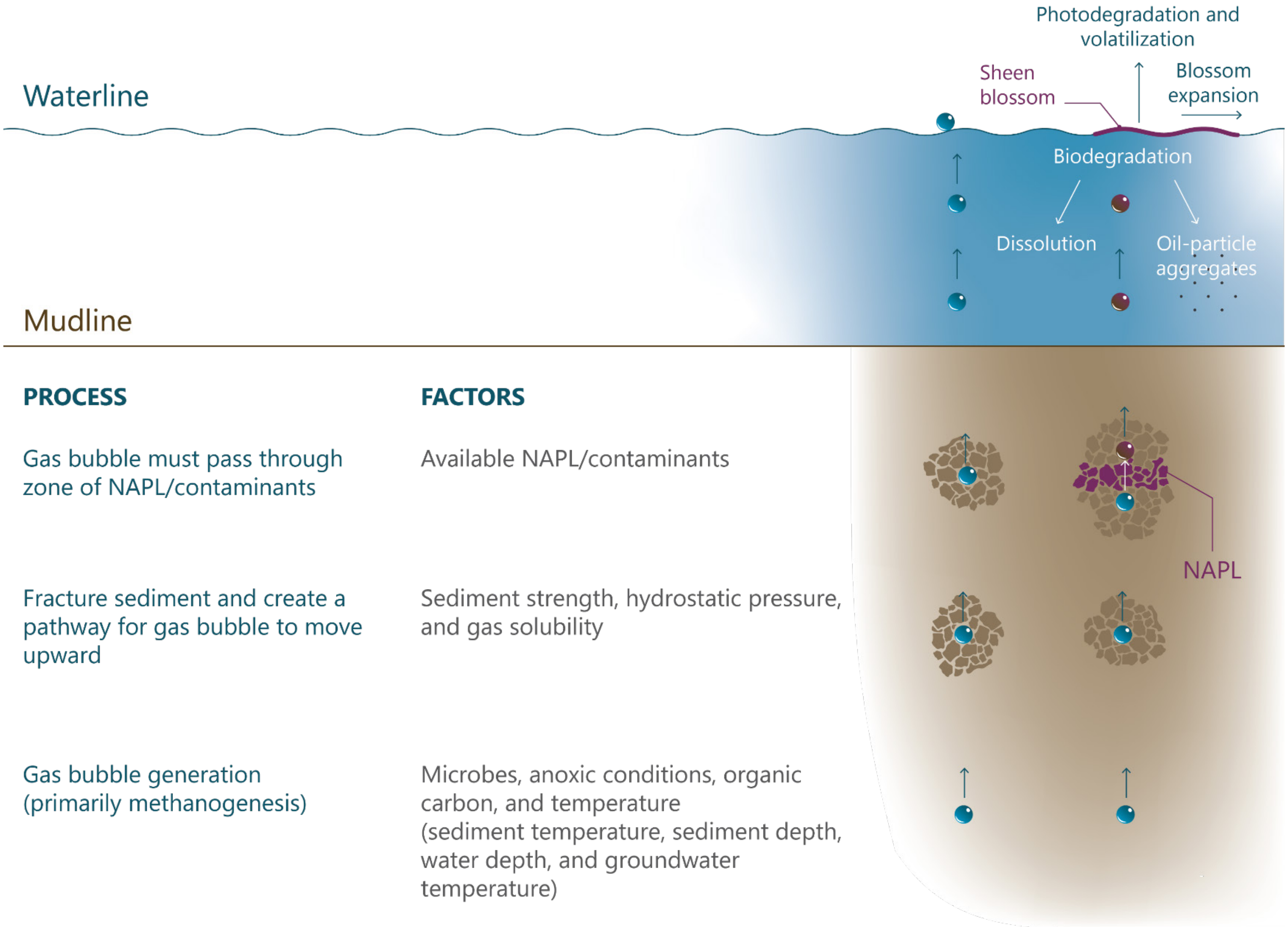
Figure D4-20
Sediment Temperature Depth Profiles – 2017 Pilot Study
Gas Ebullition Evaluation
Newtown Creek RI/FS



PROCESS	FACTORS
Gas bubble must pass through zone of NAPL/contaminants	Available NAPL/contaminants
Fracture sediment and create a pathway for gas bubble to move upward	Sediment strength, hydrostatic pressure, and gas solubility
Gas bubble generation (primarily methanogenesis)	Microbes, anoxic conditions, organic carbon, and temperature (sediment temperature, sediment depth, water depth, and groundwater temperature)

Notes:
The majority of methanogenesis is expected in shallower sediments where temperatures are warmest and sediment strengths are weakest.
The USEPA is still investigating the potential for ebullition sediment fractures to serve as preferential flow paths for contaminated groundwater into surface water.

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Figure D5-1
Gas Ebullition Processes
Gas Ebullition Evaluation
Newtown Creek RI/FS

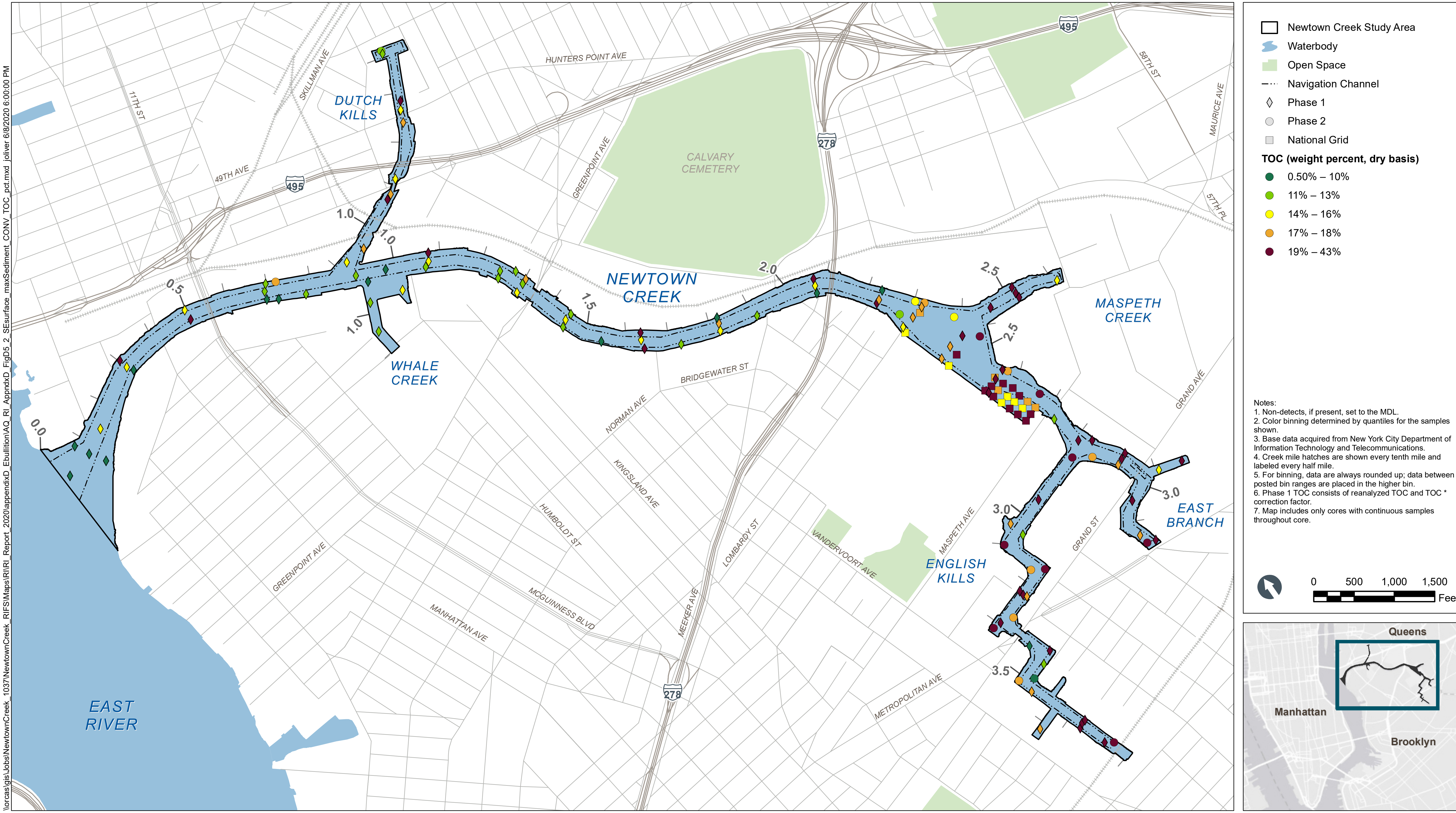

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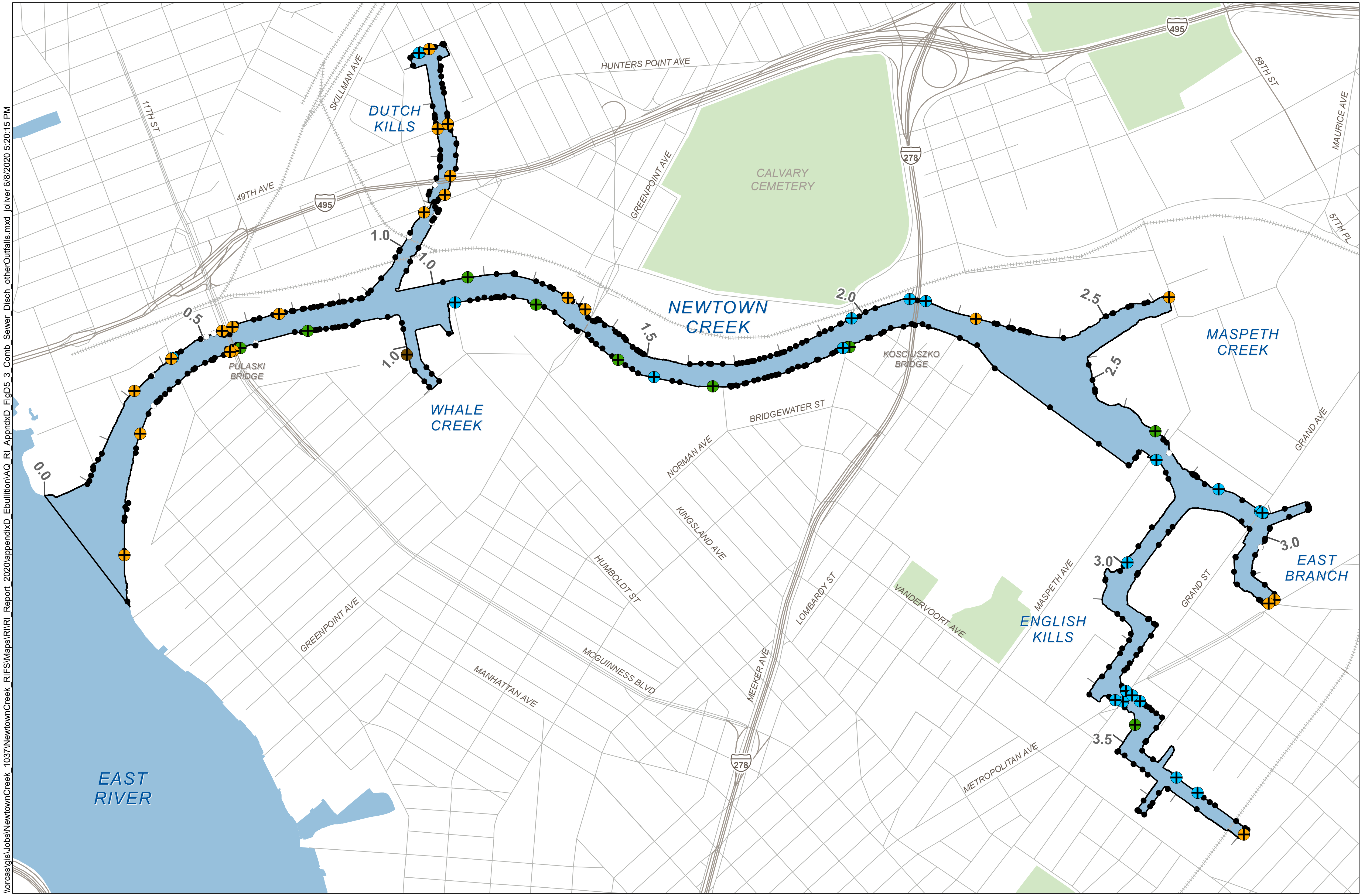
Figure D5-2
Maximum TOC Concentrations in Sediment
Gas Ebullition Evaluation
Newtown Creek RI/FS



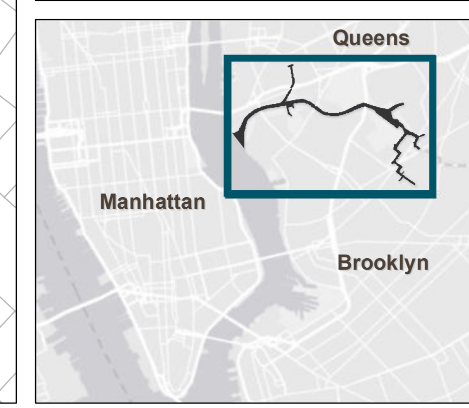
Newtown Creek Study Area
Waterbody
Open Space

Point Source Discharge

- Individually Permitted Stormwater and Wastewater Discharges
- Combined Sewer Overflow
- WWTP Treated Effluent Overflow
- MS4 and Major Stormwater Discharges
- Direct Discharges from Individual Sites
- Highway Drains

Notes:
1. Outfall locations are approximate and based on best available information.
2. Additional information about these outfalls is provided in the outfall inventory in Appendix E.
3. Base data acquired from New York City Department of Information Technology and Telecommunications.
4. Creek mile hatches are shown every tenth mile and labeled every half mile.
5. WWTP: Wastewater Treatment Plant

0 500 1,000 1,500
Feet



ANCHOR QEA

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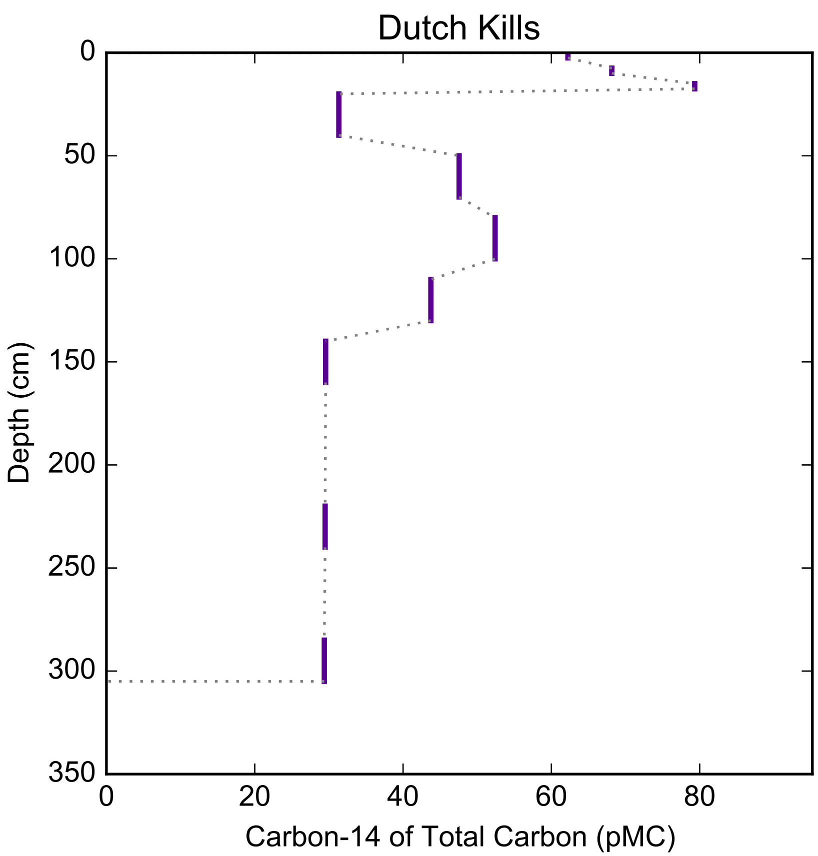
Figure D5-3
Combined Sewer Overflow and Other Outfalls that Discharge to the Study Area
Gas Ebullition Evaluation
Newtown Creek RI/FS



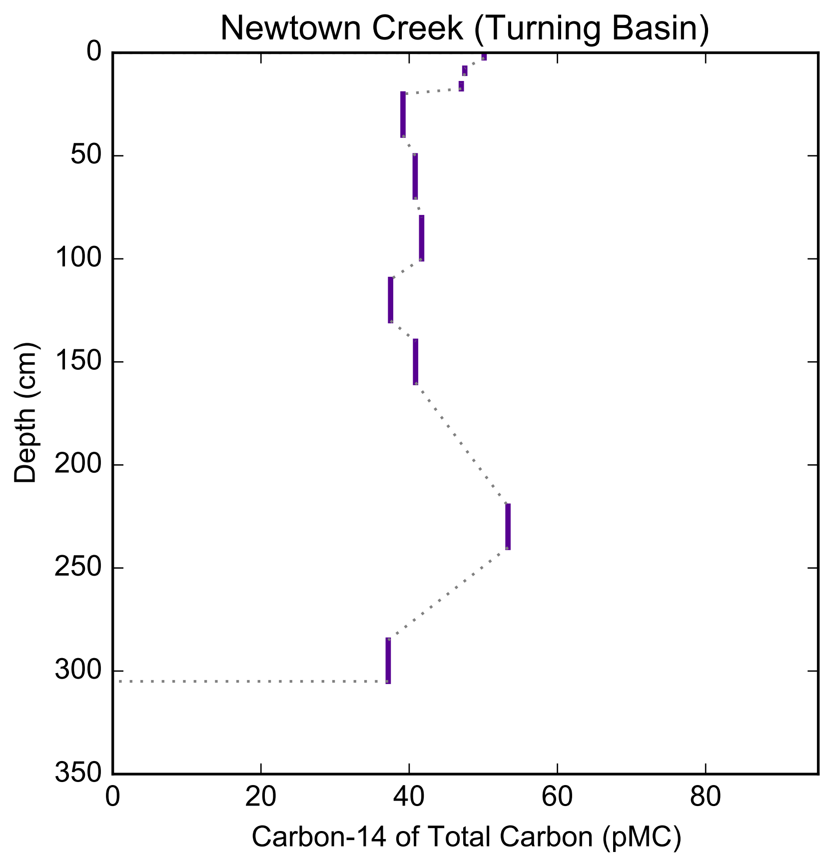


Figure D5-4
Sediment Concentration of Carbon-14 of Total Carbon: Depth Profile
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: If present, results less than detection limit set to the method detection limit and plotted with dashed vertical lines.
pMC = percent modern carbon.

- Newtown Creek Study Area
- Navigation Channel
- Boom
- Street
- Creek Mile
- Combined Sewer Overflow
- WWTP Treated Effluent Overflow
- Outfall

Sheen Blossom Observations

Year
- 2015
- 2016
- 2017

NAPL Category for Top 5-Feet of Sediment
- Category 1A
- Category 1B
- Category 2
- Category 3

Total Organic Carbon (weight percent, dry basis)
- 4.1% – 11%
- 12% – 14%
- 15% – 16%
- 17% – 18%
- 19% – 43%

Notes:
1. Base data acquired from New York City Department of Information Technology and Telecommunications.
2. Creek mile hatches are shown every tenth mile and labeled every half mile.
3. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and NAPL categories are based on the most notable shake-test in the top 5 feet of sediment for each core.
4. Sheen blossom observations were observed during the 2015, 2016, and 2017 Field Gas Ebullition Surveys.
5. Color binning determined by quantiles for the thiessens shown. Break values for numerical classification bins are rounded up. Values between displayed ranges are placed in the higher bin and are shown for observations in the upper 5 feet of sediment.
6. Non-detects, if present, set to the MDL.
7. Phase 1 TOC consists of reanalyzed TOC and TOC * correction factor.
8. Map includes only cores with continuous samples throughout core.
9. WWTP: Wastewater Treatment Plant

Feet

0 250 500 750 1,000

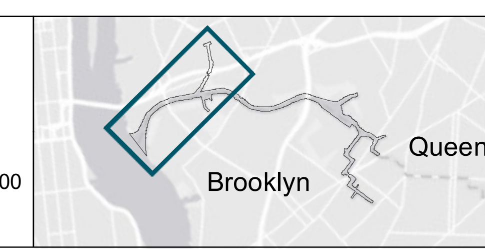


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Figure D5-5a

Apparent Gas Ebullition Observations and Maximum TOC Concentration in Top 5-Feet of Sediment for Newtown Creek, Whale Creek, and Dutch Kills

Gas Ebullition Evaluation

Newtown Creek RI/FS

Newtown Creek Study Area
Navigation Channel
Boom
Street
Creek Mile

Combined Sewer Overflow
WWTP Treated Effluent Overflow
Outfall

Sheen Blossom Observations

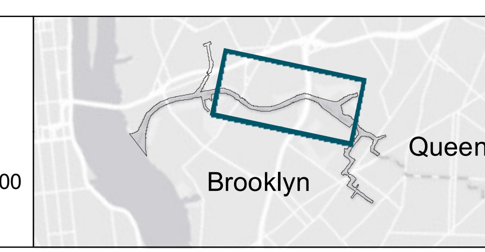
Year
2015
2016
2017

NAPL Category for Top 5-Feet of Sediment
Category 1A
Category 1B
Category 2
Category 3

Total Organic Carbon (weight percent, dry basis)
4.1% – 11%
12% – 14%
15% – 16%
17% – 18%
19% – 43%

Notes:
1. Base data acquired from New York City Department of Information Technology and Telecommunications.
2. Creek mile hatches are shown every tenth mile and labeled every half mile.
3. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and NAPL categories are based on the most notable shake-test in the top 5 feet of sediment for each core.
4. Sheen blossom observations were observed during the 2015, 2016, and 2017 Field Gas Ebullition Surveys.
5. Color binning determined by quantiles for the thiessens shown. Break values for numerical classification bins are rounded up. Values between displayed ranges are placed in the higher bin and are shown for observations in the upper 5 feet of sediment.
6. Non-detects, if present, set to the MDL.
7. Phase 1 TOC consists of reanalyzed TOC and TOC * correction factor.
8. Map includes only cores with continuous samples throughout core.
9. WWTP: Wastewater Treatment Plant

Feet
0 250 500 750 1,000



\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_EbullitionAQ_RI_AppndxD_FigD5_5abc_ApparentGasEbObservations_MaxTOCinTop5ft.mxd joliver 8/29/2021 3:32:27 PM

ANCHOR QEA

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Figure D5-5b
Apparent Gas Ebullition Observations and Maximum TOC Concentration in Top 5-Feet of Sediment for Newtown Creek, Turning Basin, and Maspeth Creek
Gas Ebullition Evaluation
Newtown Creek RI/FS

Newtown Creek Study Area
Navigation Channel
Boom
Street
Creek Mile

Combined Sewer Overflow
WWTP Treated Effluent Overflow
Outfall

Sheen Blossom Observations

Year
- 2015
- 2016
- 2017

NAPL Category for Top 5-Feet of Sediment
- Category 1A
- Category 1B
- Category 2
- Category 3

Total Organic Carbon (weight percent, dry basis)
- 4.1% – 11%
- 12% – 14%
- 15% – 16%
- 17% – 18%
- 19% – 43%

Notes:
1. Base data acquired from New York City Department of Information Technology and Telecommunications.
2. Creek mile hatches are shown every tenth mile and labeled every half mile.
3. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and NAPL categories are based on the most notable shake-test in the top 5 feet of sediment for each core.
4. Sheen blossom observations were observed during the 2015, 2016, and 2017 Field Gas Ebullution Surveys.
5. Color binning determined by quantiles for the thiessens shown. Break values for numerical classification bins are rounded up. Values between displayed ranges are placed in the higher bin and are shown for observations in the upper 5 feet of sediment.
6. Non-detects, if present, set to the MDL.
7. Phase 1 TOC consists of reanalyzed TOC and TOC * correction factor.
8. Map includes only cores with continuous samples throughout core.
9. WWTP: Wastewater Treatment Plant

Feet

0 250 500 750 1,000

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Figure D5-5c
Apparent Gas Ebullition Observations and Maximum TOC Concentration in Top 5-Feet of Sediment for East Branch and English Kills
Gas Ebullition Evaluation
Newtown Creek RI/FS

Newtown Creek Study Area
Navigation Channel
Boom
Street
Creek Mile

Combined Sewer Overflow
WWTP Treated Effluent Overflow
Outfall

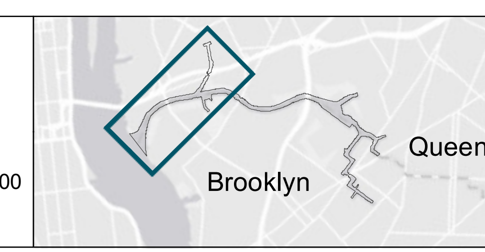
Sheen Blossom Observations Year
2015
2016
2017

NAPL Category for Sediment
Category 1A
Category 1B
Category 2
Category 3

Total Organic Carbon (weight percent, dry basis)
5.7% – 12%
13% – 15%
16% – 17%
18% – 22%
23% – 43%

Notes:
1. Aerial imagery acquired from New York State (2016).
2. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and NAPL categories are based on the most notable shake-test in sediment for each core.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. Sheen blossom observations were observed during the 2015, 2016, and 2017 Field Gas Ebullition Surveys.
5. Color binning determined by quantiles for the thiessens shown. Break values for numerical classification bins are rounded up. Values between displayed ranges are placed in the higher bin and are shown for observations in the upper 5 feet of sediment.
6. Non-detects, if present, set to the MDL.
7. Phase 1 TOC consists of reanalyzed TOC and TOC * correction factor.
8. Map includes only cores with continuous samples throughout core.
9. WWTP: Wastewater Treatment Plant

Feet
0 250 500 750 1,000



ANCHOR QEA

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Figure D5-5d
Apparent Gas Ebullition Observations and Maximum TOC Concentration in All Sediment Depths for Newtown Creek, Whale Creek, and Dutch Kills
Gas Ebullition Evaluation
Newtown Creek RI/FS

\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_EbullitionAQ_RI_AppndxD_FigD5_5def_ApparentGasEbObservations_MaxTOCinSubsurface.mxd joliver 8/29/2021 3:30:44 PM

- Newtown Creek Study Area
- Navigation Channel
- Boom
- Street
- Creek Mile
- Combined Sewer Overflow
- WWTP Treated Effluent Overflow
- Outfall

Sheen Blossom Observations

Year
- 2015
- 2016
- 2017

NAPL Category for Sediment
- Category 1A
- Category 1B
- Category 2
- Category 3

Total Organic Carbon (weight percent, dry basis)
- 5.7% – 12%
- 13% – 15%
- 16% – 17%
- 18% – 22%
- 23% – 43%

Notes:
1. Aerial imagery acquired from New York State (2016).
2. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and NAPL categories are based on the most notable shake-test in sediment for each core.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. Sheen blossom observations were observed during the 2015, 2016, and 2017 Field Gas Ebullution Surveys.
5. Color binning determined by quantiles for the thiessens shown. Break values for numerical classification bins are rounded up. Values between displayed ranges are placed in the higher bin and are shown for observations in the upper 5 feet of sediment.
6. Non-detects, if present, set to the MDL.
7. Phase 1 TOC consists of reanalyzed TOC and TOC * correction factor.
8. Map includes only cores with continuous samples throughout core.
9. WWTP: Wastewater Treatment Plant

Feet
0 250 500 750 1,000

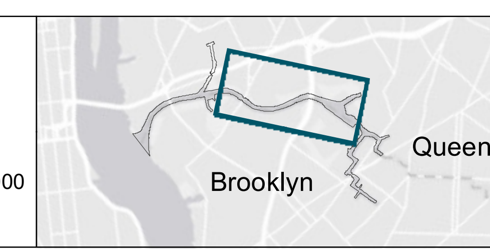

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Figure D5-5e
Apparent Gas Ebullition Observations and Maximum TOC Concentration in All Sediment Depths for Newtown Creek, Turning Basin, and Maspeth Creek
Gas Ebullition Evaluation
Newtown Creek RI/FS

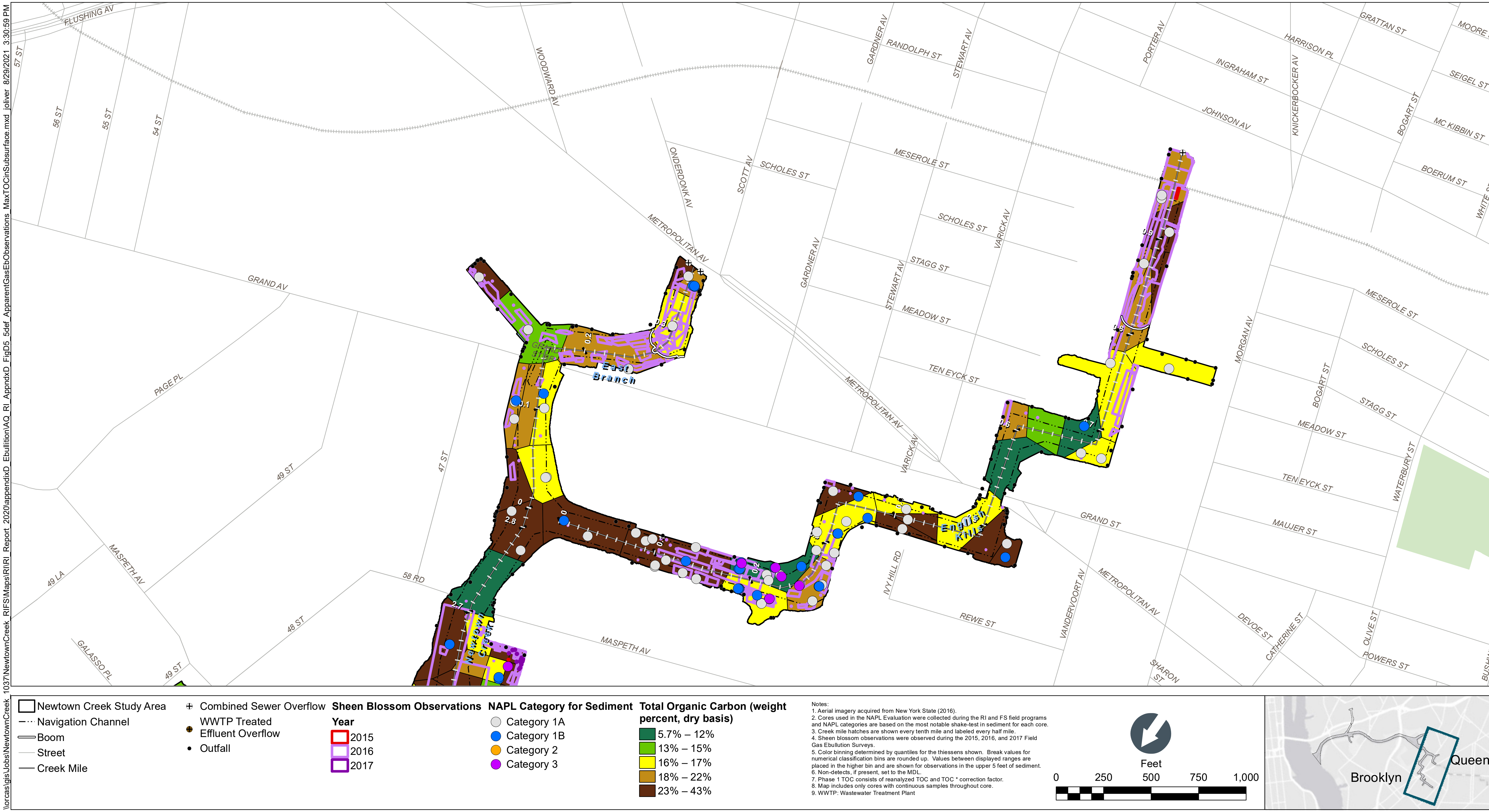

Figure D5-5f
Apparent Gas Ebullition Observations and Maximum TOC Concentration in All Sediment Depths for East Branch and English Kills
Gas Ebullition Evaluation
Newtown Creek RI/FS

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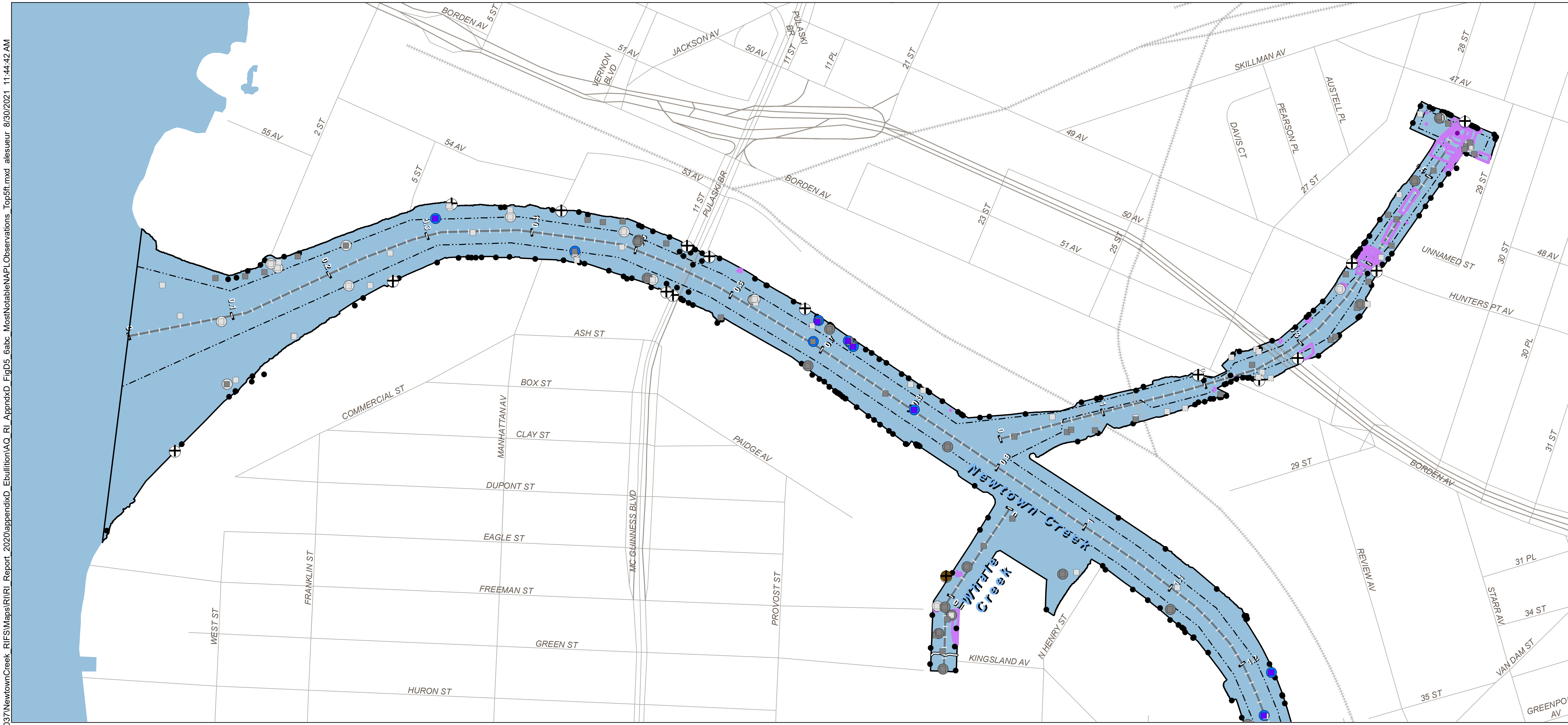


Newtown Creek Study Area
Navigation Channel
Boom
Street
Creek Mile

Combined Sewer Overflow
WWTP Treated Effluent Overflow
Outfall

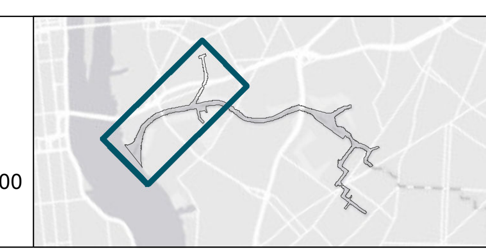
Sheen Blossom Observations Year
2015
2016
2017

Most Notable NAPL Observation in Top 5-Feet of Sediment
Saturated
Coated
Blebs
Sheen
No Visual

Shake Test
Layer
Blebs
Sheen
Negative

Notes:
1. Aerial imagery acquired from New York City Department of Information Technology and Telecommunications (2010).
2. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and visual and shake test NAPL observations represent the most notable observation in the top 5 feet of sediment.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. WWTP: Wastewater Treatment Plant

Feet
0 250 500 750 1,000



ANCHOR QEA

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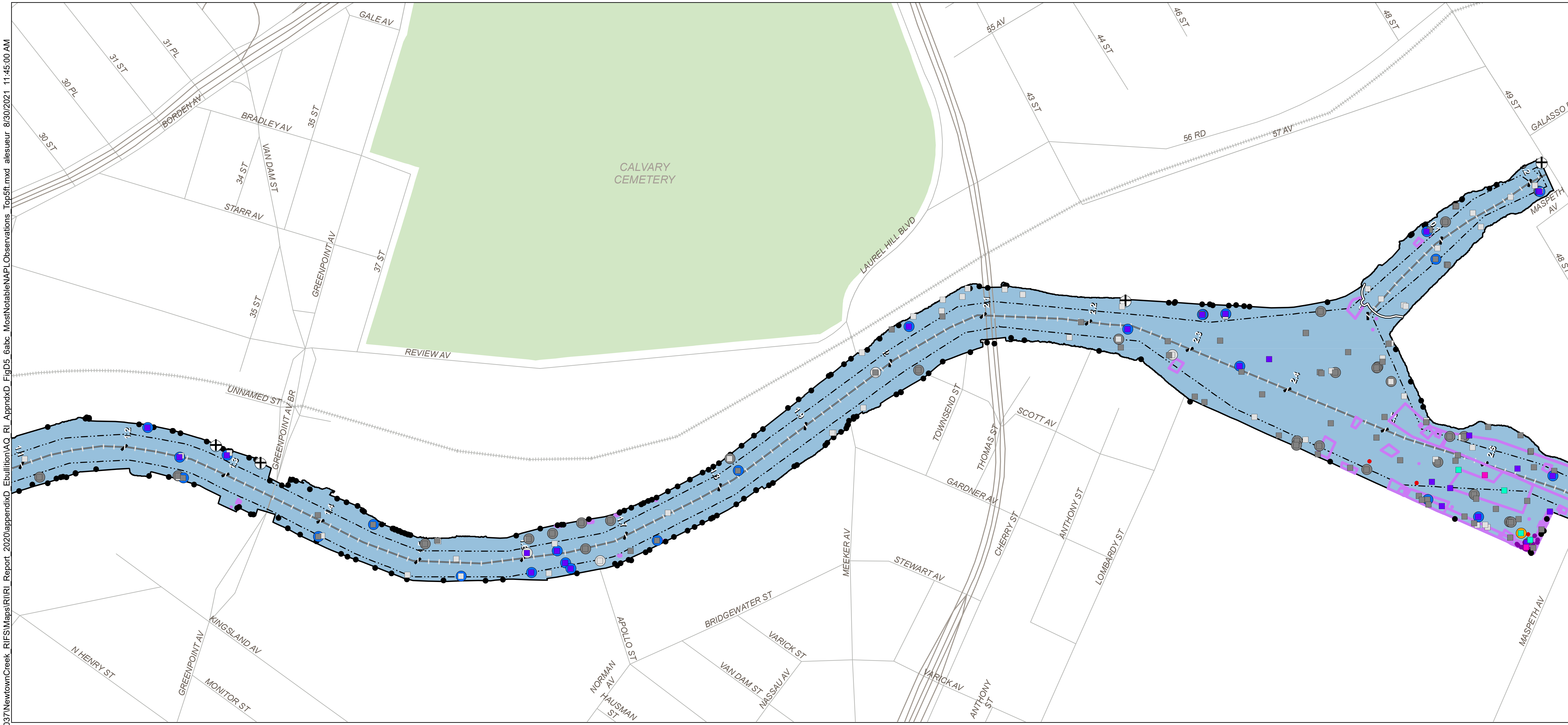
Figure D5-6a
Most Notable NAPL Observations in Top 5-Feet of Sediment for Newtown Creek, Whale Creek, and Dutch Kills
Gas Ebullition Evaluation
Newtown Creek RI/FS



\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_EbullitionAQ_RI_AppndxD_FigD5_6abc_MostNotableNAPLObservations_Top5ft.mxd alesueur 8/30/2021 11:45:00 AM

Newtown Creek Study Area
Navigation Channel
Boom
Street
Creek Mile

Combined Sewer Overflow
WWTP Treated Effluent Overflow
Outfall

Sheen Blossom Observations

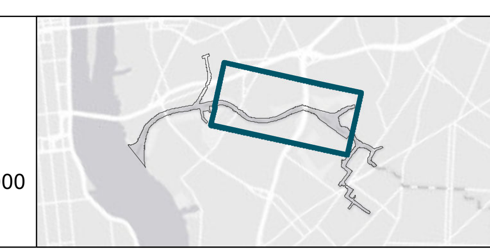
Year
2015
2016
2017

Most Notable NAPL Observation in Top 5-Feet of Sediment
Saturated
Coated
Blebs
Sheen
No Visual

Shake Test
Layer
Blebs
Sheen
Negative

Notes:
1. Aerial imagery acquired from New York City Department of Information Technology and Telecommunications (2010).
2. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and visual and shake test NAPL observations represent the most notable observation in the top 5 feet of sediment.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. WWTP: Wastewater Treatment Plant

Feet
0 250 500 750 1,000



ANCHOR QEA

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Figure D5-6b
Most Notable NAPL Observations in Top 5-Feet of Sediment for Newtown Creek, Turning Basin, and Maspeth Creek
Gas Ebullition Evaluation
Newtown Creek RI/FS

Newtown Creek Study Area
Navigation Channel
Boom
Street
Creek Mile

Combined Sewer Overflow
WWTP Treated Effluent Overflow
Outfall

Sheen Blossom Observations Year
2015
2016
2017

Most Notable NAPL Observation in Top 5-Feet of Sediment
Saturated
Coated
Blebs
Sheen
No Visual

Shake Test
Layer
Blebs
Sheen
Negative

Notes:
1. Aerial imagery acquired from New York City Department of Information Technology and Telecommunications (2010).
2. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and visual and shake test NAPL observations represent the most notable observation in the top 5 feet of sediment.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. WWTP: Wastewater Treatment Plant

Feet
0 250 500 750 1,000

\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_EbullitionAQ_RI_AppndxD_FigD5_6abc_MostNotableNAPLObservations_Top5ft.mxd alesueur 8/30/2021 11:45:18 AM

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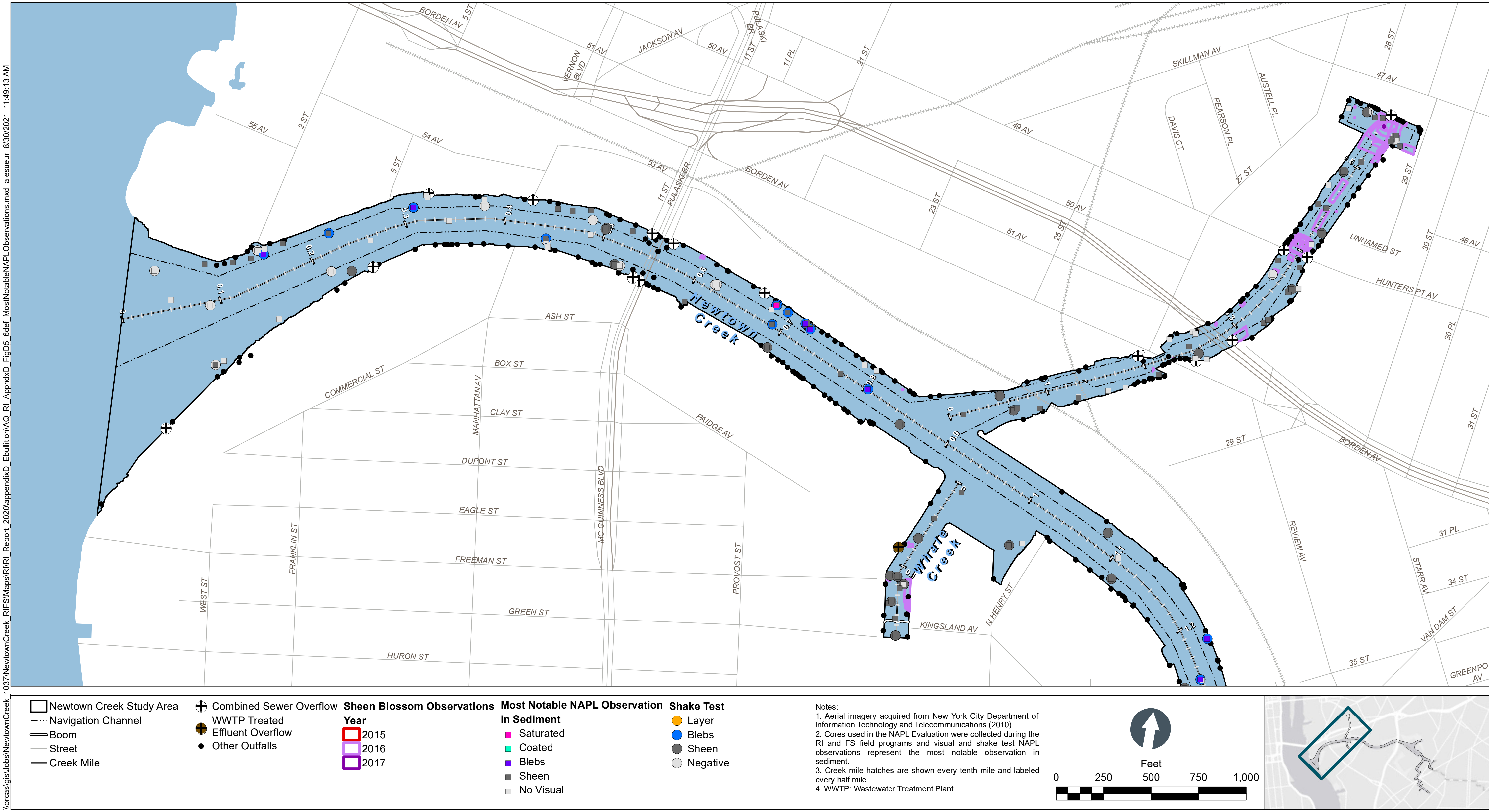
Figure D5-6c
Most Notable NAPL Observations in Top 5-Feet of Sediment for East Branch and English Kills
Gas Ebullition Evaluation
Newtown Creek RI/FS



Notes:
1. Aerial imagery acquired from New York City Department of Information Technology and Telecommunications (2010).
2. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and visual and shake test NAPL observations represent the most notable observation in sediment.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. WWTP: Wastewater Treatment Plant

\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_Ebullition\AQ_RI_AppndxD_FigD5_6def_MostNotableNAPLObservations.mxd alesueur 8/30/2021 11:49:13 AM

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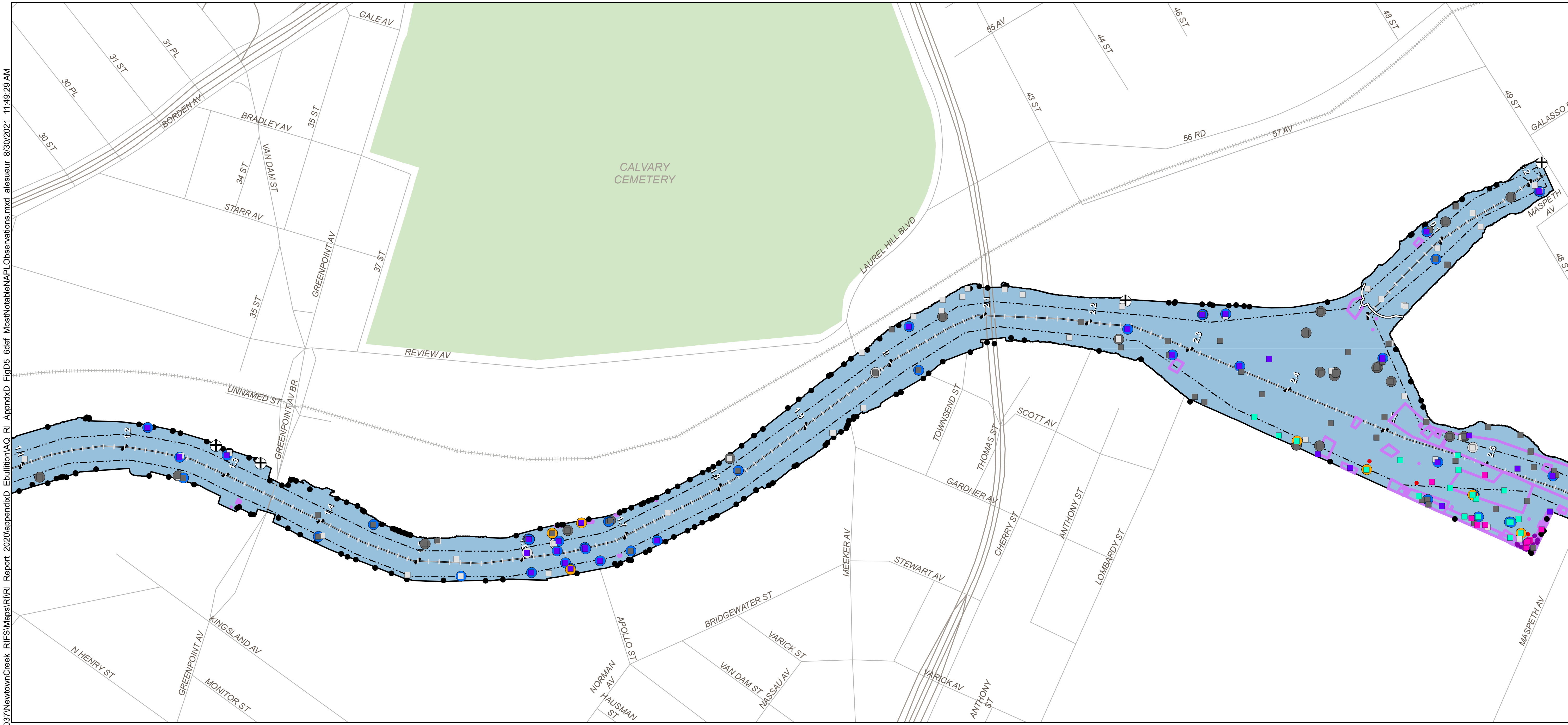
Figure D5-6d
Most Notable NAPL Observations in All Sediment Depths for Newtown Creek, Whale Creek, and Dutch Kills
Gas Ebullition Evaluation
Newtown Creek RI/FS



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Newtown Creek Study Area
Navigation Channel
Boom
Street
Creek Mile

Combined Sewer Overflow
WWTP Treated Effluent Overflow
Other Outfalls

Sheen Blossom Observations Year
2015
2016
2017

Most Notable NAPL Observation in Sediment
Saturated
Coated
Blebs
Sheen
No Visual

Shake Test
Layer
Blebs
Sheen
Negative

Notes:
1. Aerial imagery acquired from New York City Department of Information Technology and Telecommunications (2010).
2. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and visual and shake test NAPL observations represent the most notable observation in sediment.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. WWTP: Wastewater Treatment Plant

Feet
0 250 500 750 1,000

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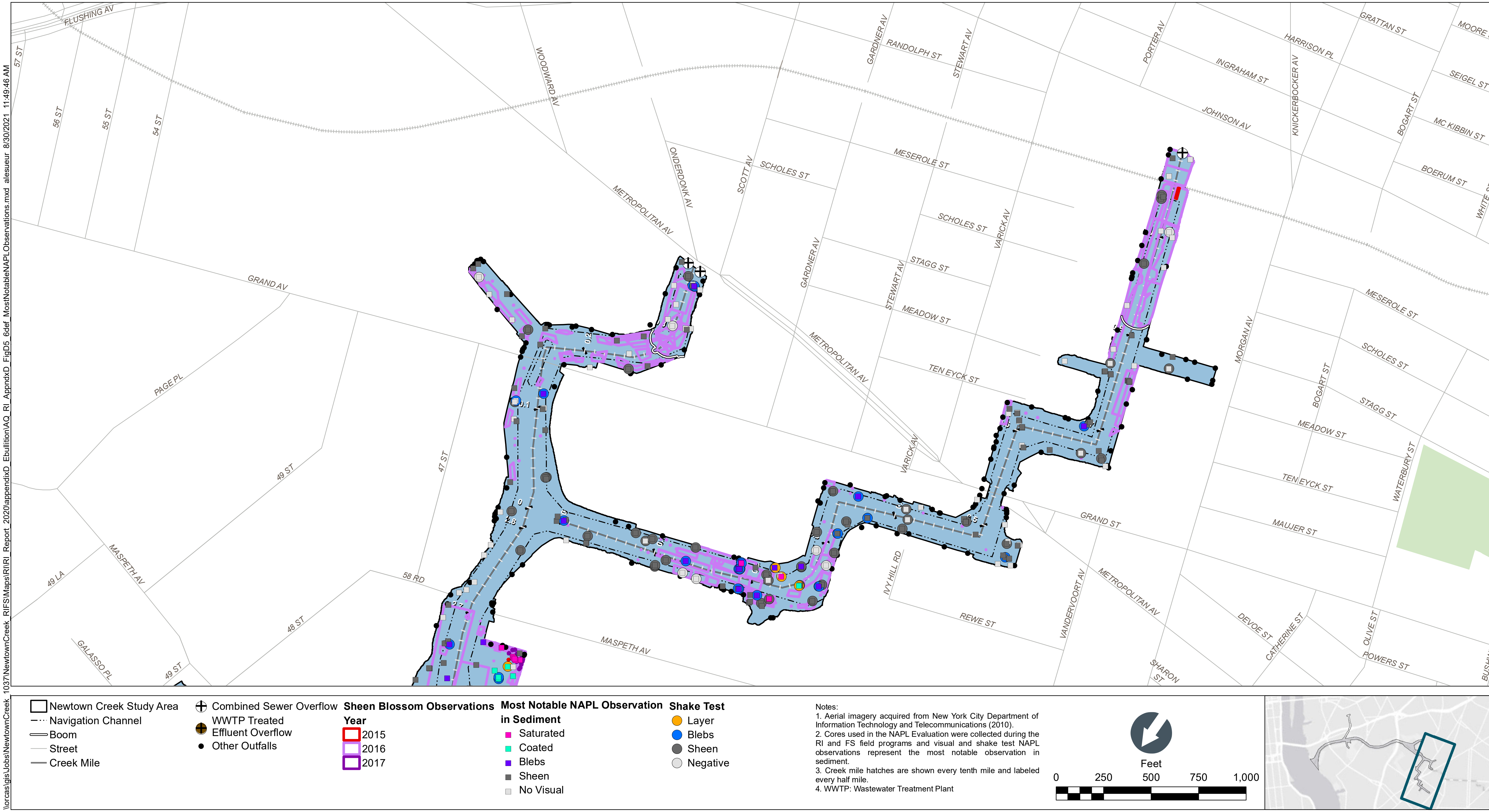
Figure D5-6e
Most Notable NAPL Observations in All Sediment Depths
for Newtown Creek, Turning Basin, and Maspeth Creek
Gas Ebullition Evaluation
Newtown Creek RI/FS



Notes:
1. Aerial imagery acquired from New York City Department of Information Technology and Telecommunications (2010).
2. Cores used in the NAPL Evaluation were collected during the RI and FS field programs and visual and shake test NAPL observations represent the most notable observation in sediment.
3. Creek mile hatches are shown every tenth mile and labeled every half mile.
4. WWTP: Wastewater Treatment Plant

\\orcas\gis\Jobs\NewtownCreek_1037\NewtownCreek_RIFS\Maps\RI\RI_Report_2020\appendixD_EbullitionAQ_RI_AppndxD_FigD5_6def_MostNotableNAPLObservations.mxd alesueur 8/30/2021 11:49:46 AM

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Figure D5-6f
Most Notable NAPL Observations in All Sediment Depths
for East Branch and English Kills
Gas Ebullition Evaluation
Newtown Creek RI/FS

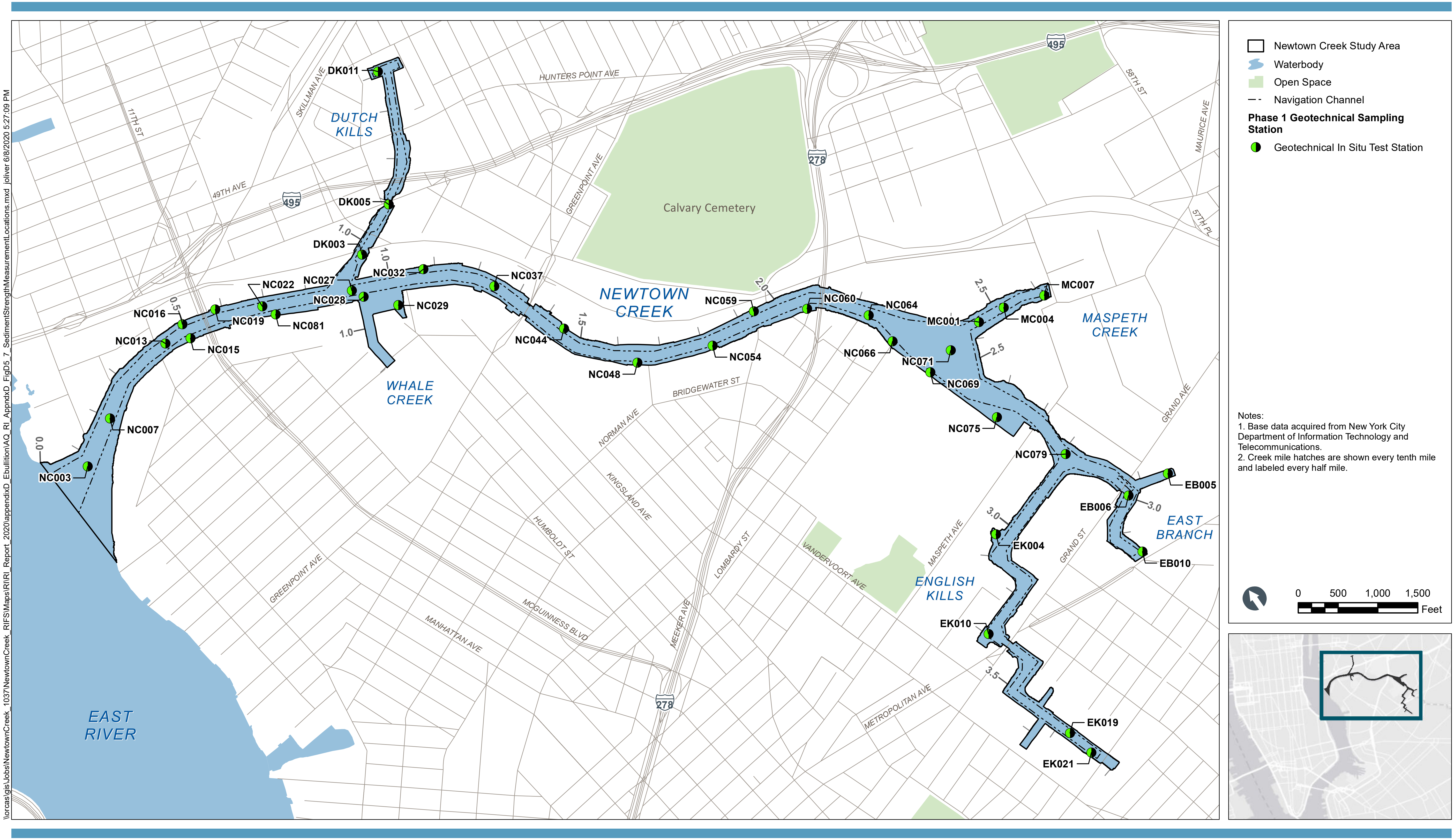

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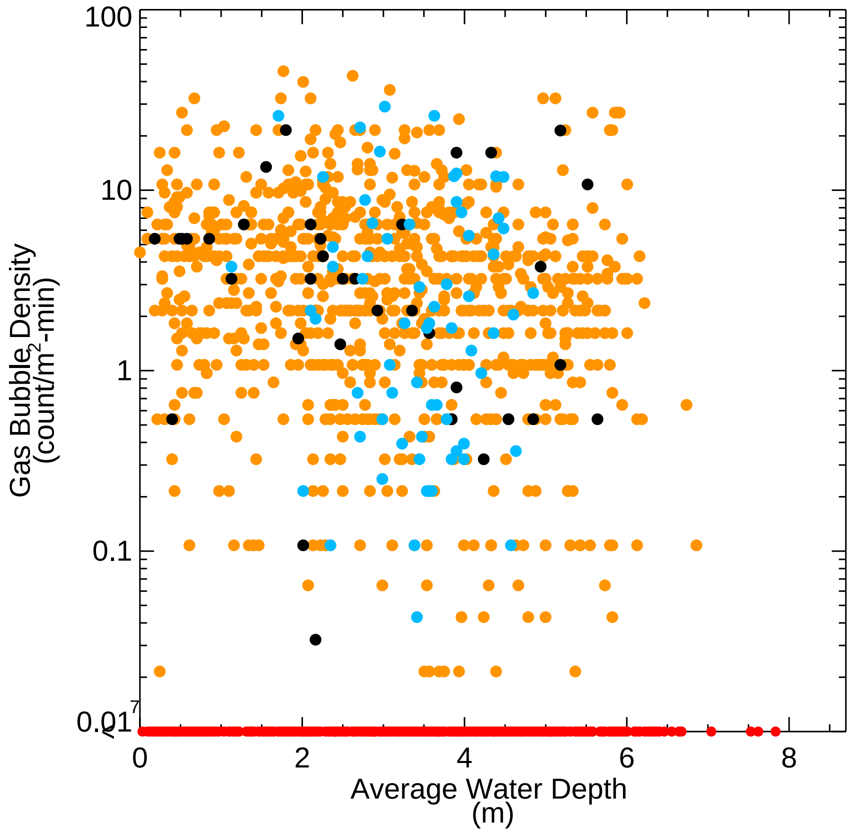
Figure D5-7
Sediment Strength Measurement Locations
Gas Ebullition Evaluation
Newtown Creek RI/FS



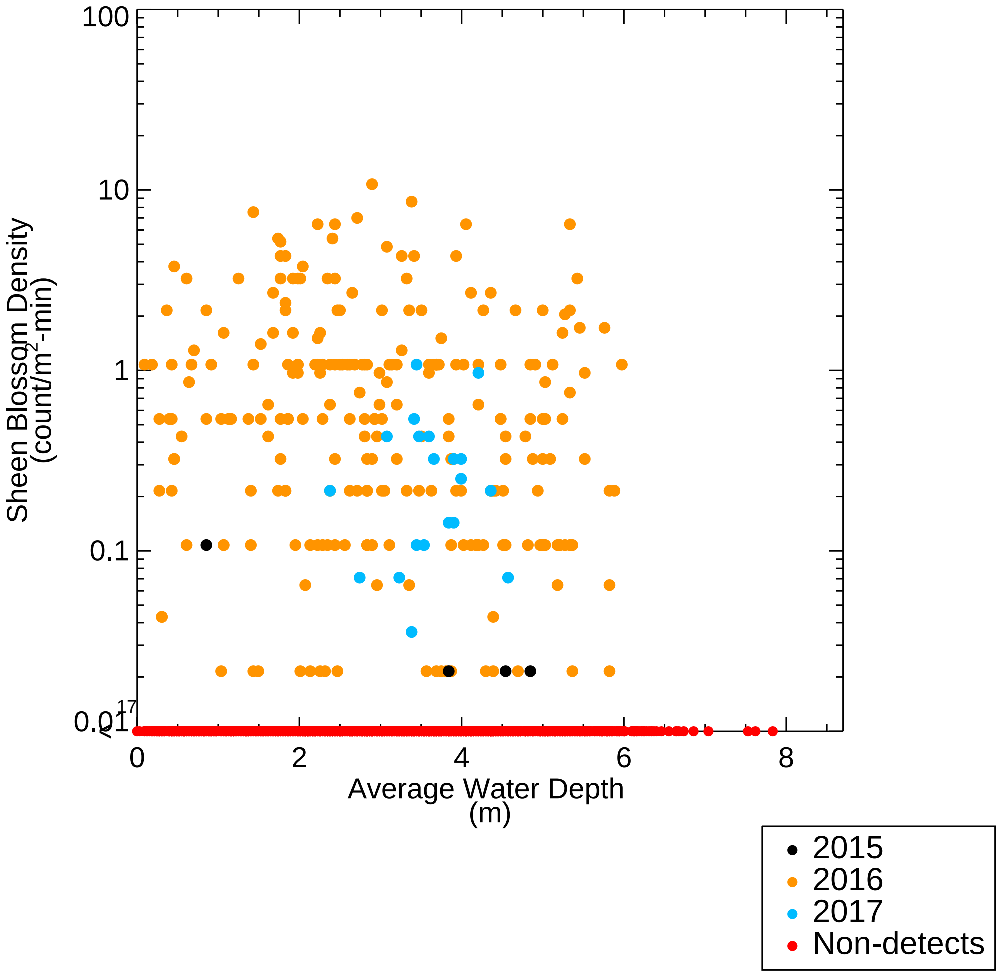


Figure D5-8

Sheen Blossom and Gas Bubble Density versus Water Depth
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Non-detects plotted at minimum of y-axis range.

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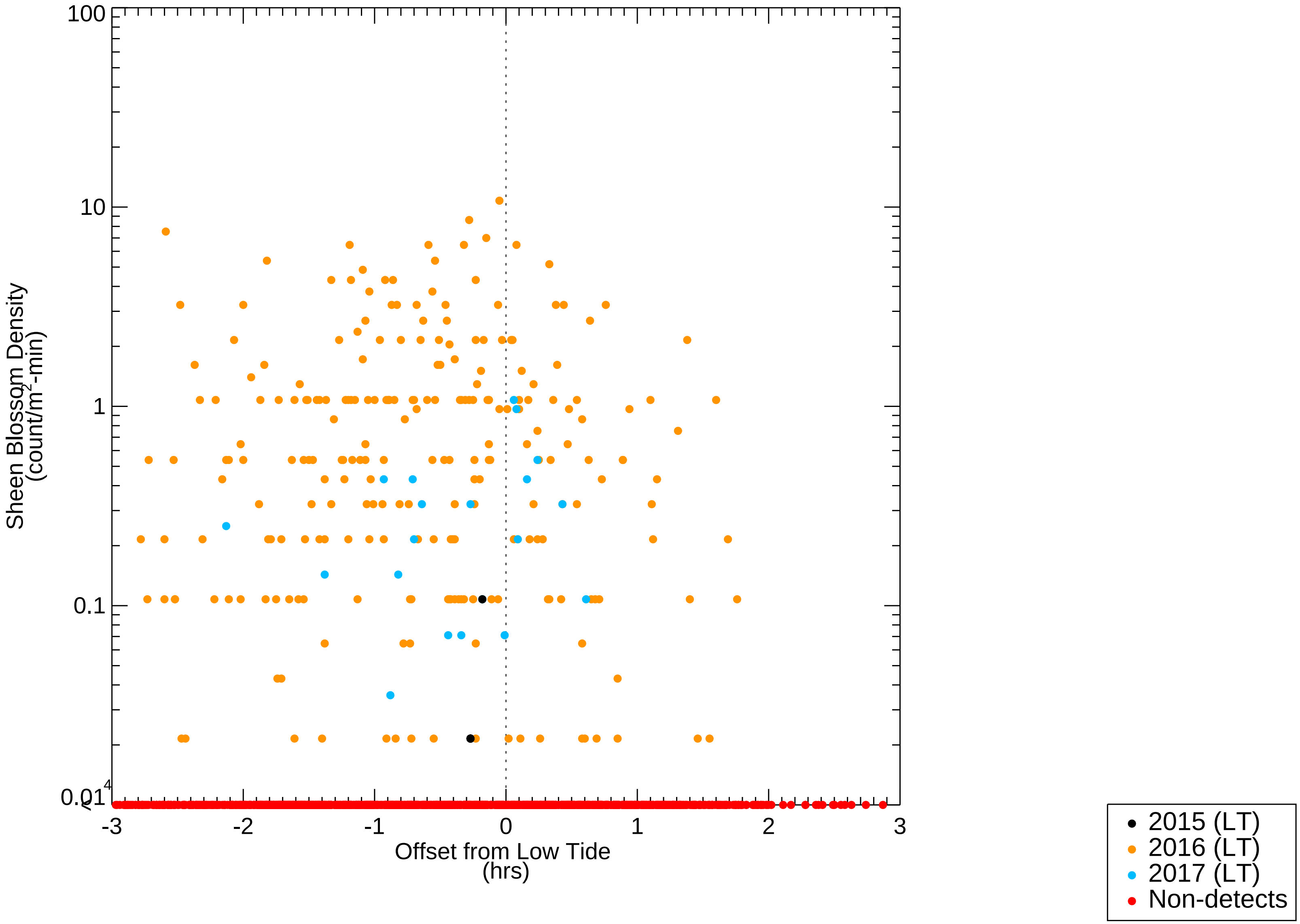

Figure D5-9

Sheen Blossom Density versus Time Relative to Low Tide
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Non-detects plotted at minimum of y-axis range.

ANCHOR QEA

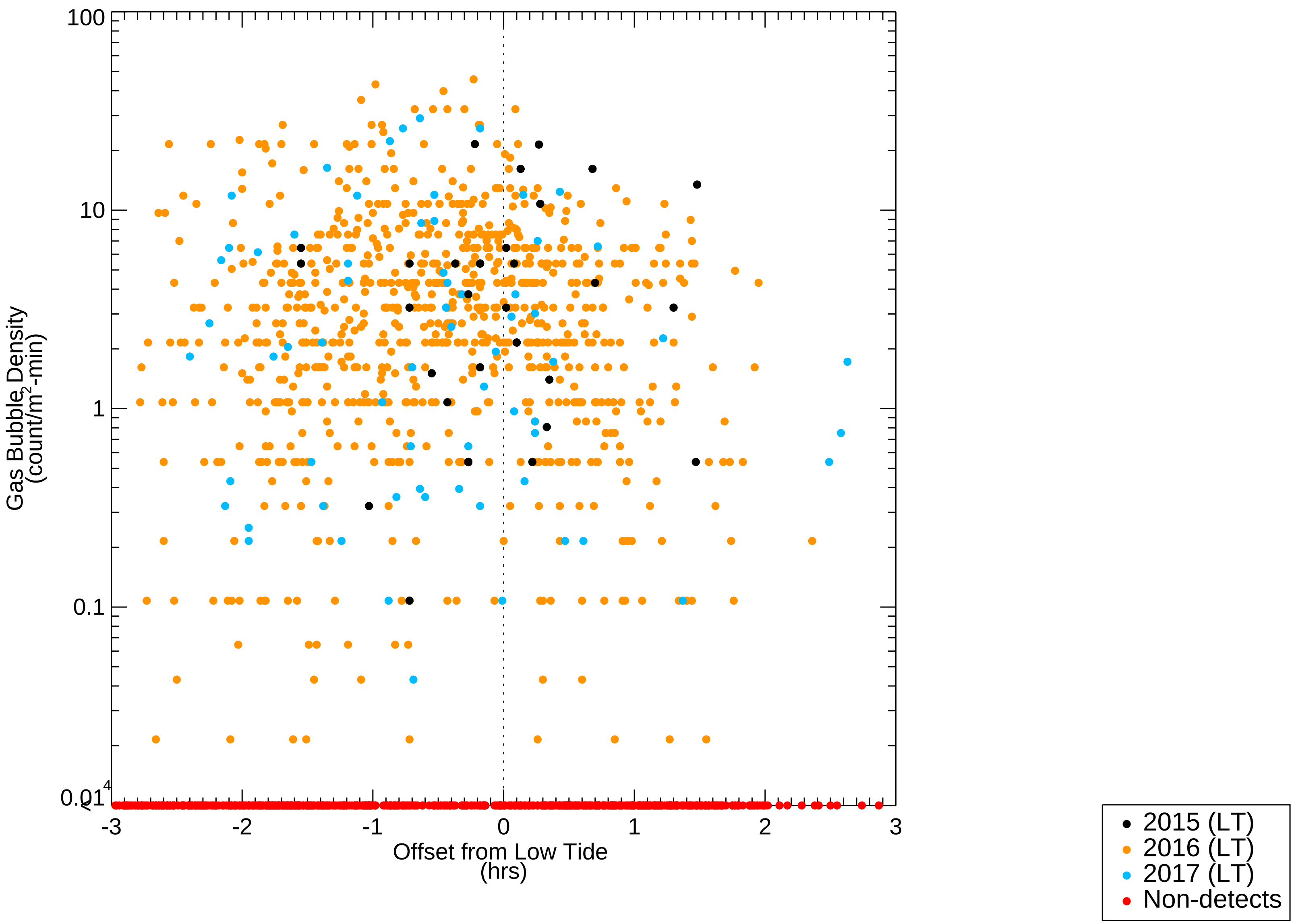

Figure D5-10

Gas Bubble Density versus Time Relative to Low Tide
Gas Ebullition Evaluation
Newtown Creek RI/FS

Note: Non-detects plotted at minimum of y-axis range.

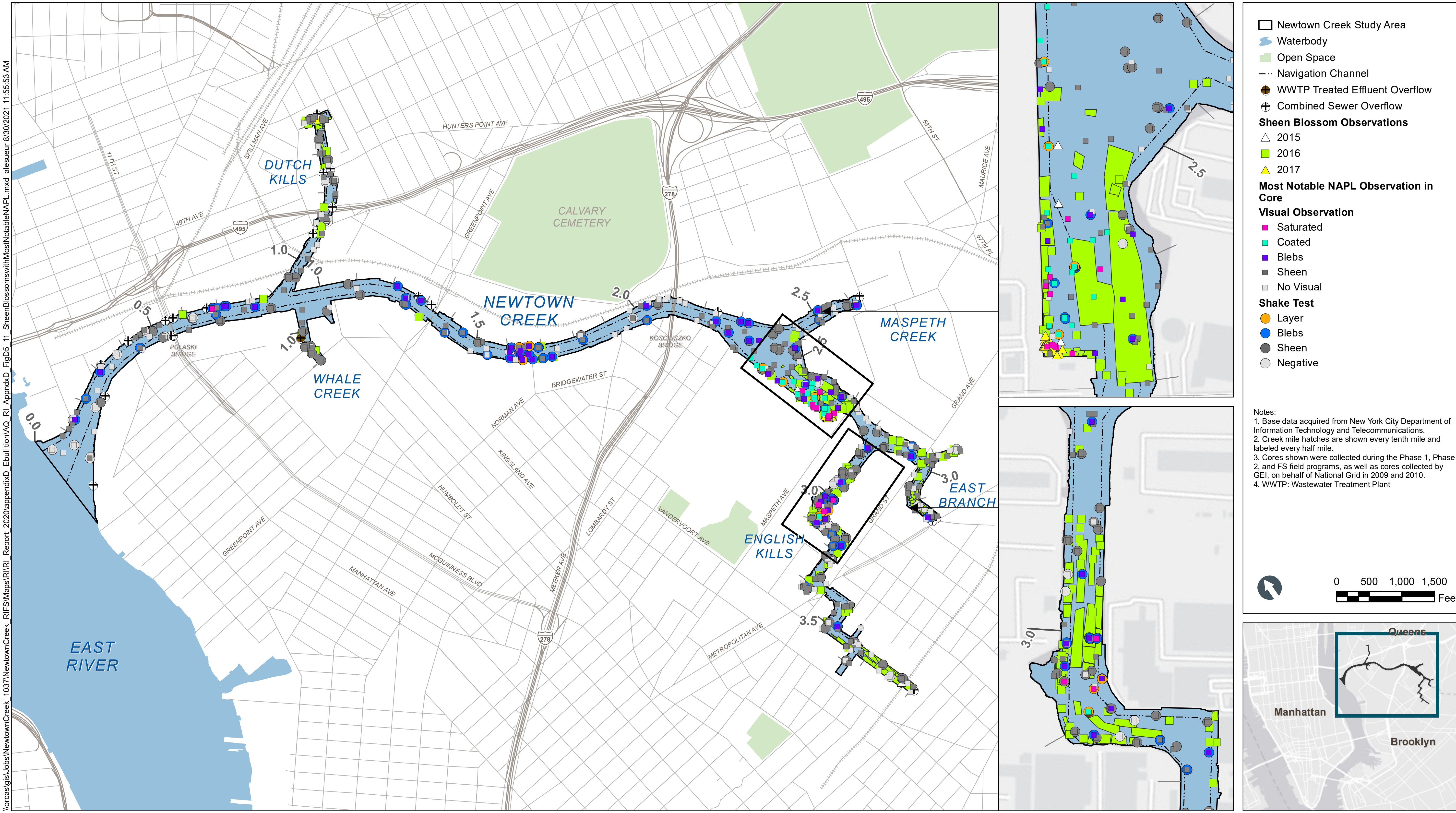

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Figure D5-11
Summary of Dynamic Sheen Observations for All Surveys
and Most Notable NAPL Observations in Sediment
Gas Ebullition Evaluation
Newtown Creek RI/FS

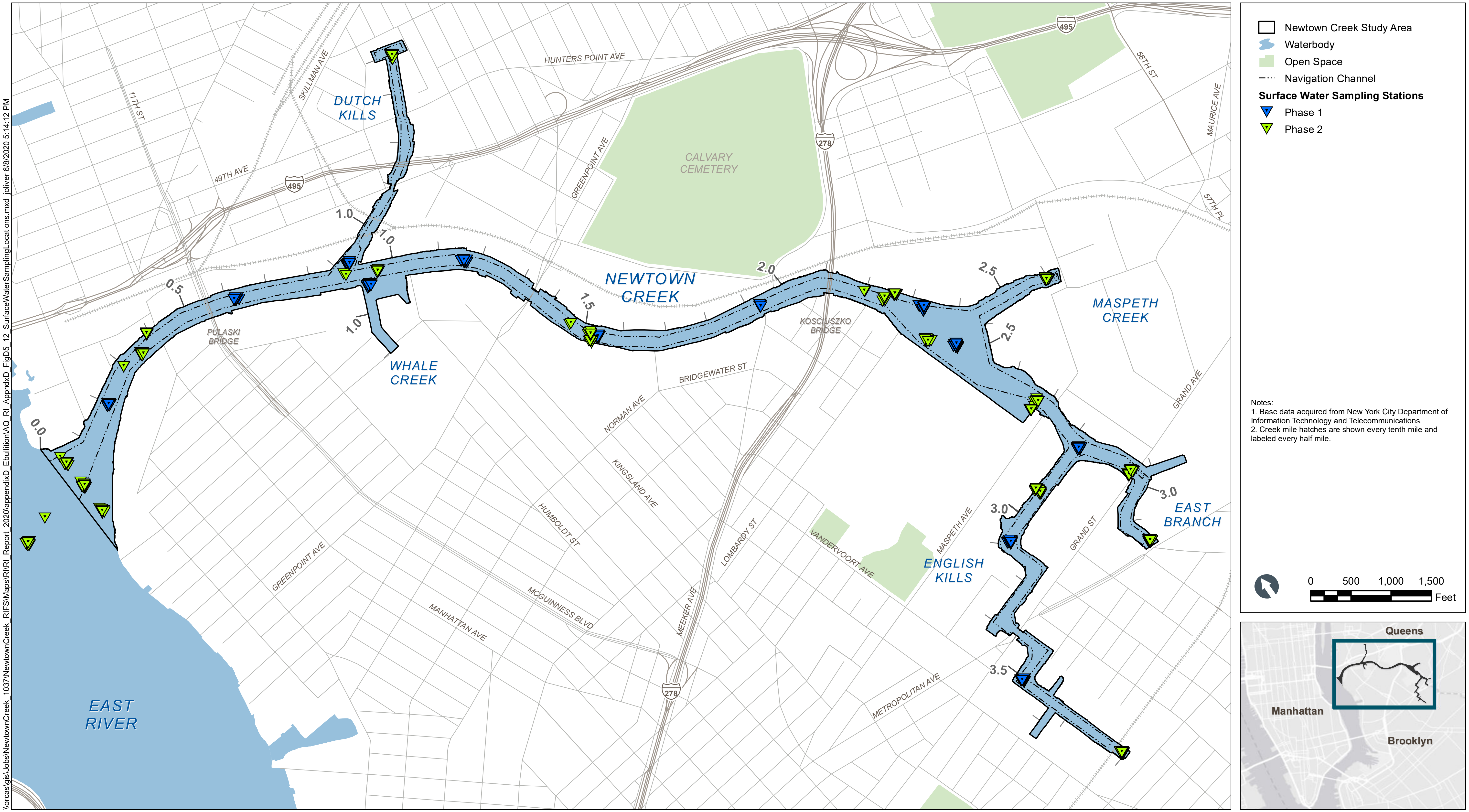

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Figure D5-12
Surface Water Sampling Stations
Gas Ebullition Evaluation
Newtown Creek RI/FS

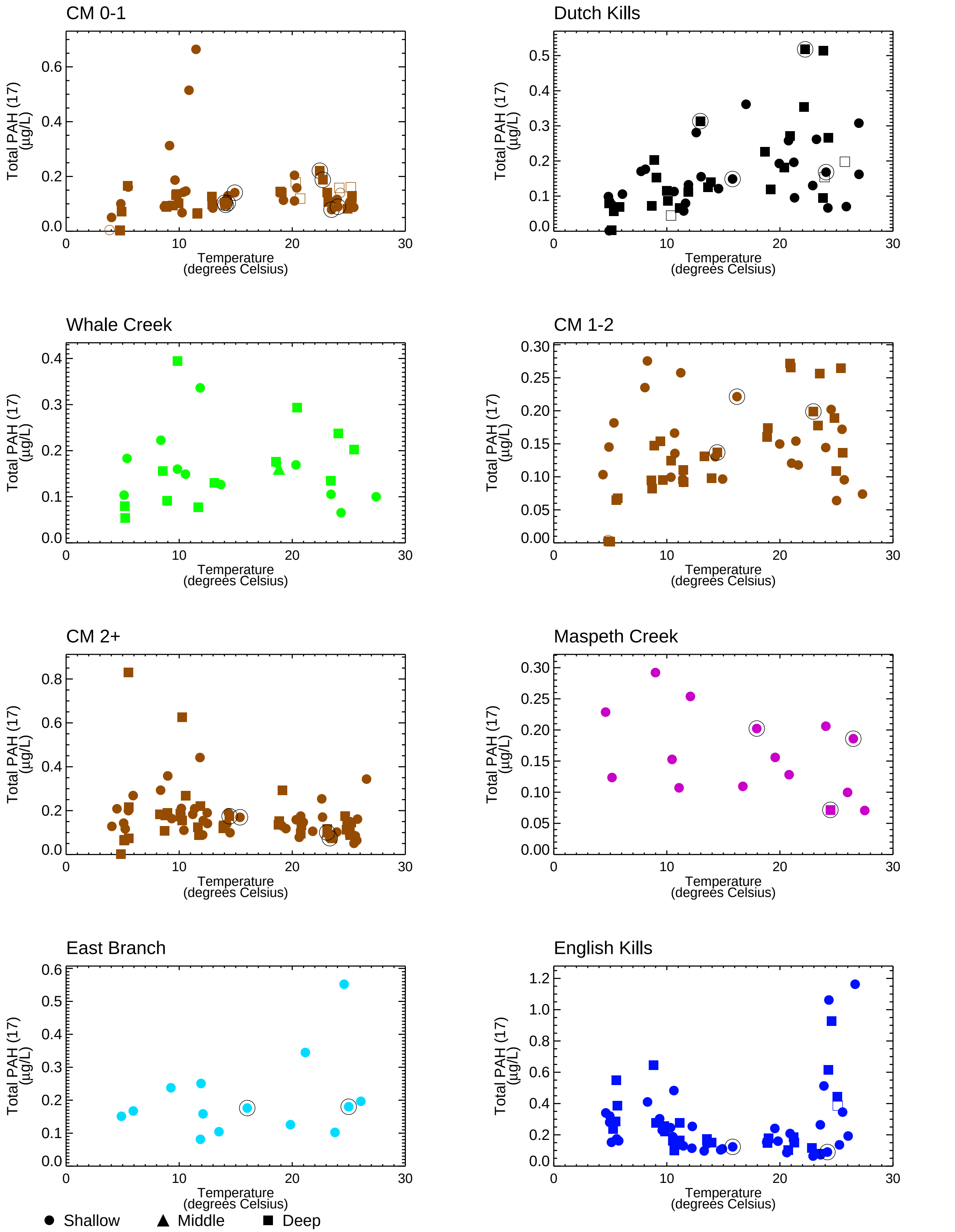


Figure D5-13a

Total PAH (17) in Surface Water During Dry Weather Sampling
versus Surface Water Temperature
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Non-detects, if present, set to the MDL and plotted with open symbol. Totals reported using Kaplan-Meier, if applicable. Samples collected during Phase 2 identified with a halo around symbol. Shallow samples collected within 3 feet of water surface, middle samples from midpoint of water depth, and deep samples collected within 3 feet of sediment surface.

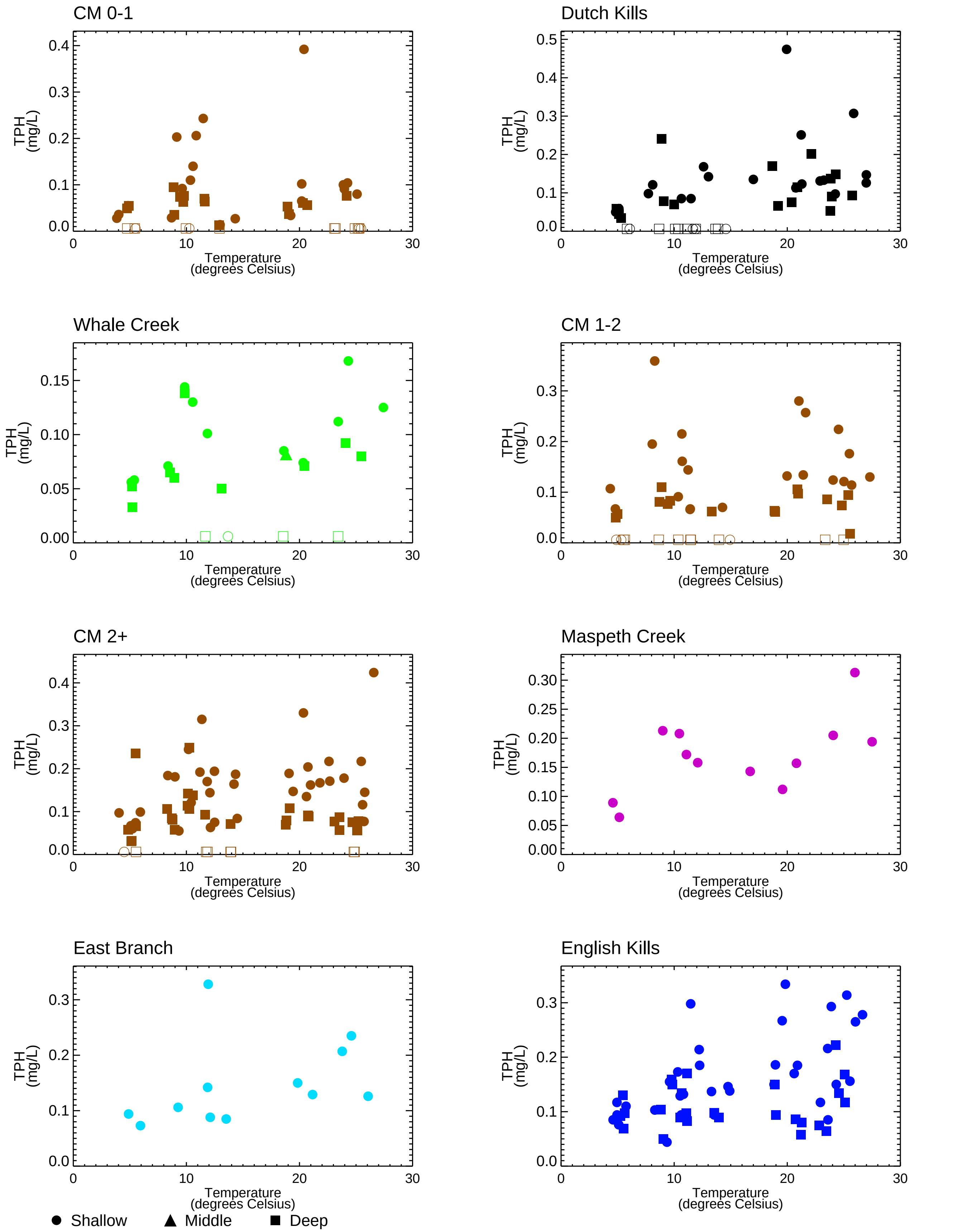


Figure D5-13b

TPH in Surface Water During Dry Weather Sampling versus Surface Water Temperature
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Non-detects, if present, set to the MDL and plotted with open symbol. TPH was not analyzed in dry weather samples collected in Phase 2. Shallow samples collected within 3 feet of water surface, middle samples from midpoint of water depth, and deep samples collected within 3 feet of sediment surface.

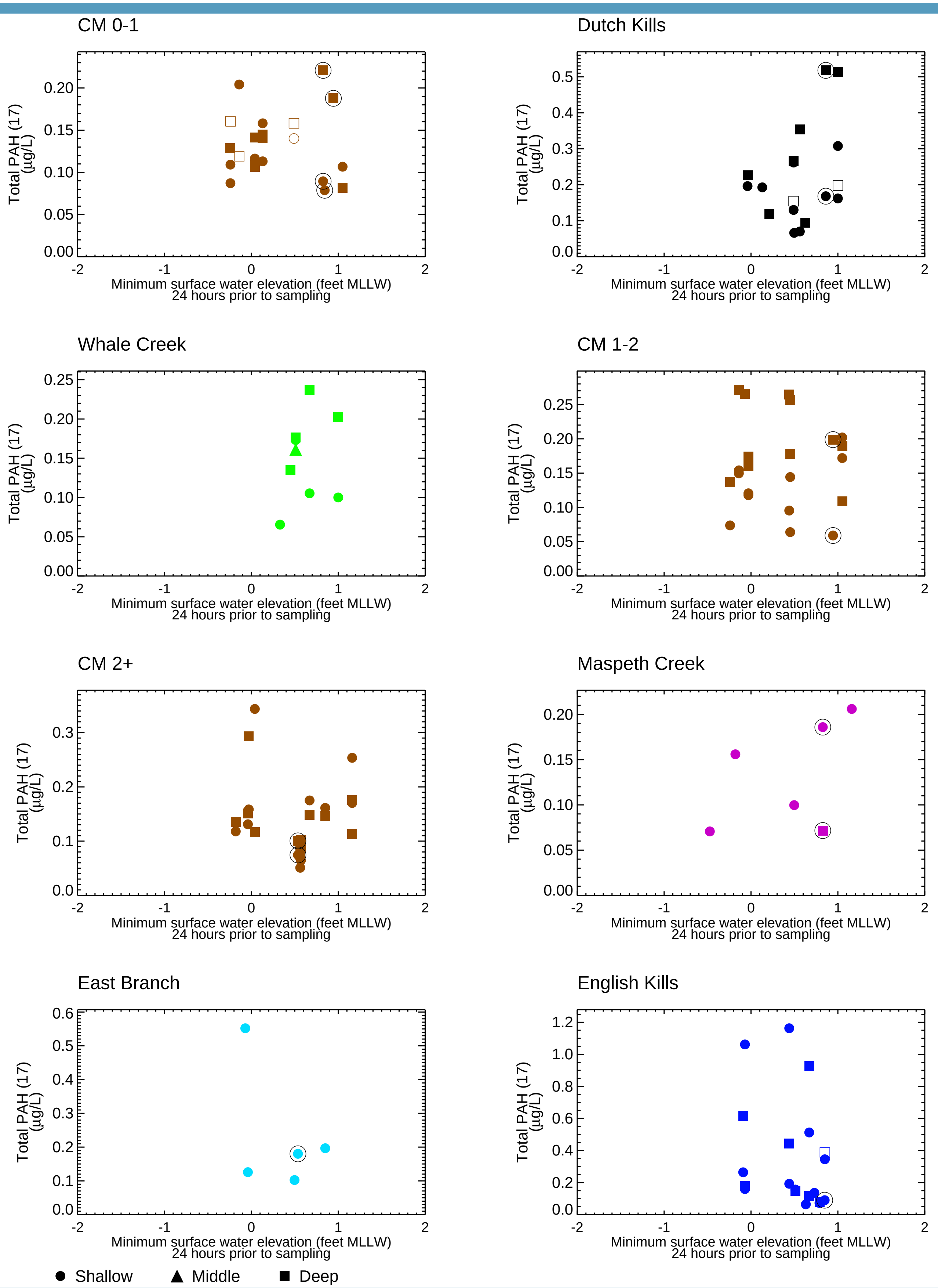


Figure D5-13c

Total PAH (17) in Surface Water During Dry Weather Sampling versus Minimum Tide Height 24 Hours Prior to Collection - June through September (2012, 2014)
Gas Ebullition Evaluation
Newtown Creek RI/FS

ANCHOR QEA

Notes: Non-detects, if present, set to the MDL and plotted with open symbol. Totals reported using Kaplan-Meier, if applicable. Samples collected during Phase 2 identified with a halo around symbol. Phase 1 samples collected in June through September 2012. Phase 2 samples collected in August 2014. Shallow samples collected within 3 feet of water surface, middle samples from midpoint of water depth, and deep samples collected within 3 feet of sediment surface. MLLW: mean lower low water.

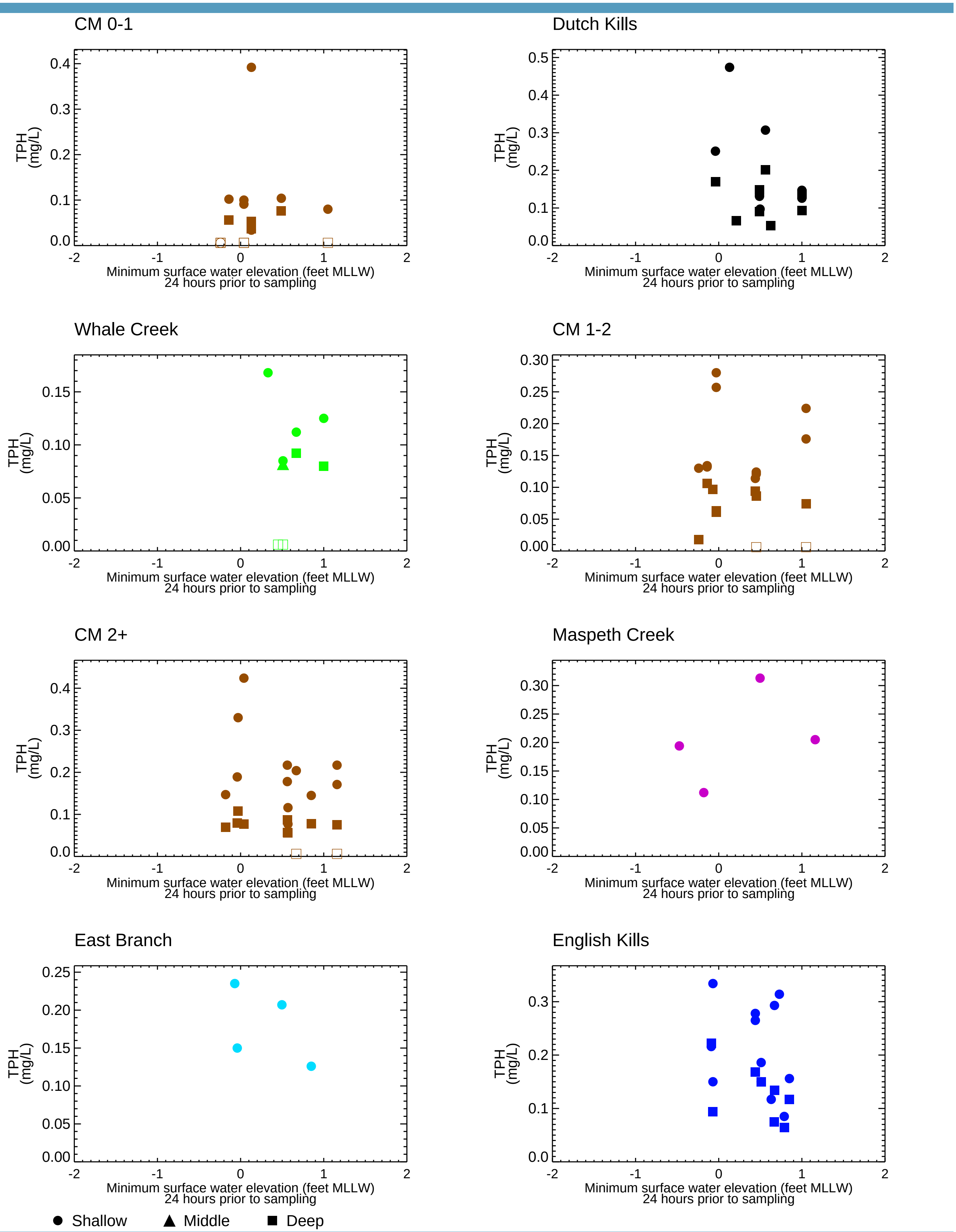


Figure D5-13d

TPH in Surface Water During Dry Weather Sampling versus Minimum Tide Height 24 Hours Prior to Collection - June through September (2012, 2014)
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Non-detects, if present set to the MDL and plotted with open symbol. TPH was not analyzed in dry weather samples collected in Phase 2. Phase 1 samples collected in June through September 2012. Shallow samples collected within 3 feet of water surface, middle samples from midpoint of water depth, and deep samples collected within 3 feet of sediment surface. MLLW: mean lower low water.

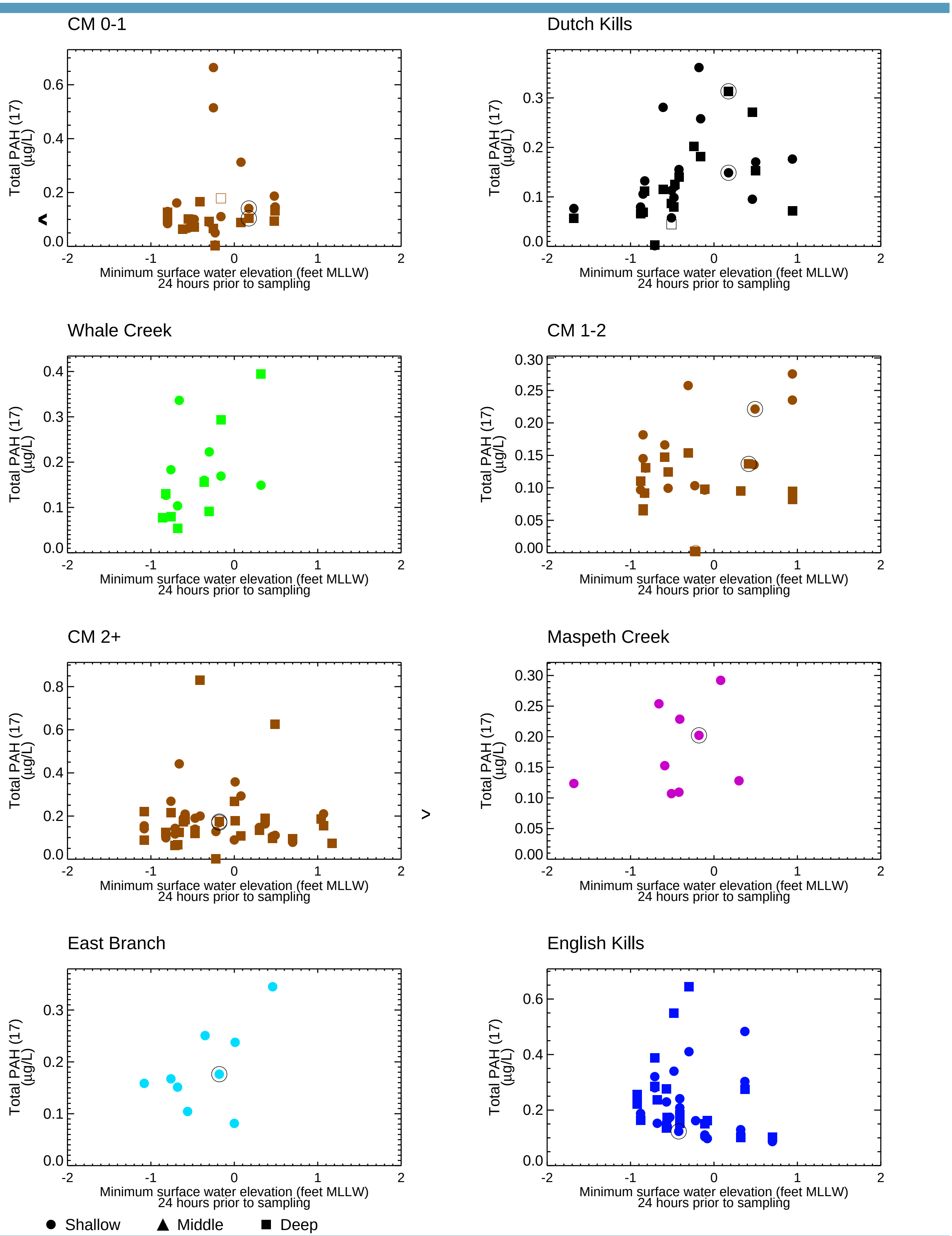


Figure D5-13e

Total PAH (17) in Surface Water During Dry Weather Sampling versus Minimum Tide Height 24 Hours Prior to Collection - October through May (2012 - 2014)
Gas Ebullition Evaluation
Newtown Creek RI/FS

ANCHOR QEA

Notes: Non-detects, if present, set to the MDL and plotted with open symbol. Totals reported using Kaplan-Meier, if applicable. Samples collected during Phase 2 identified with a halo around symbol. Phase 1 samples collected in February through May 2012, October 2012 through January 2013. Phase 2 samples collected in May 2014. Shallow samples collected within 3 feet of water surface, middle samples from midpoint of water depth, and deep samples collected within 3 feet of sediment surface. MLLW: mean lower low water.

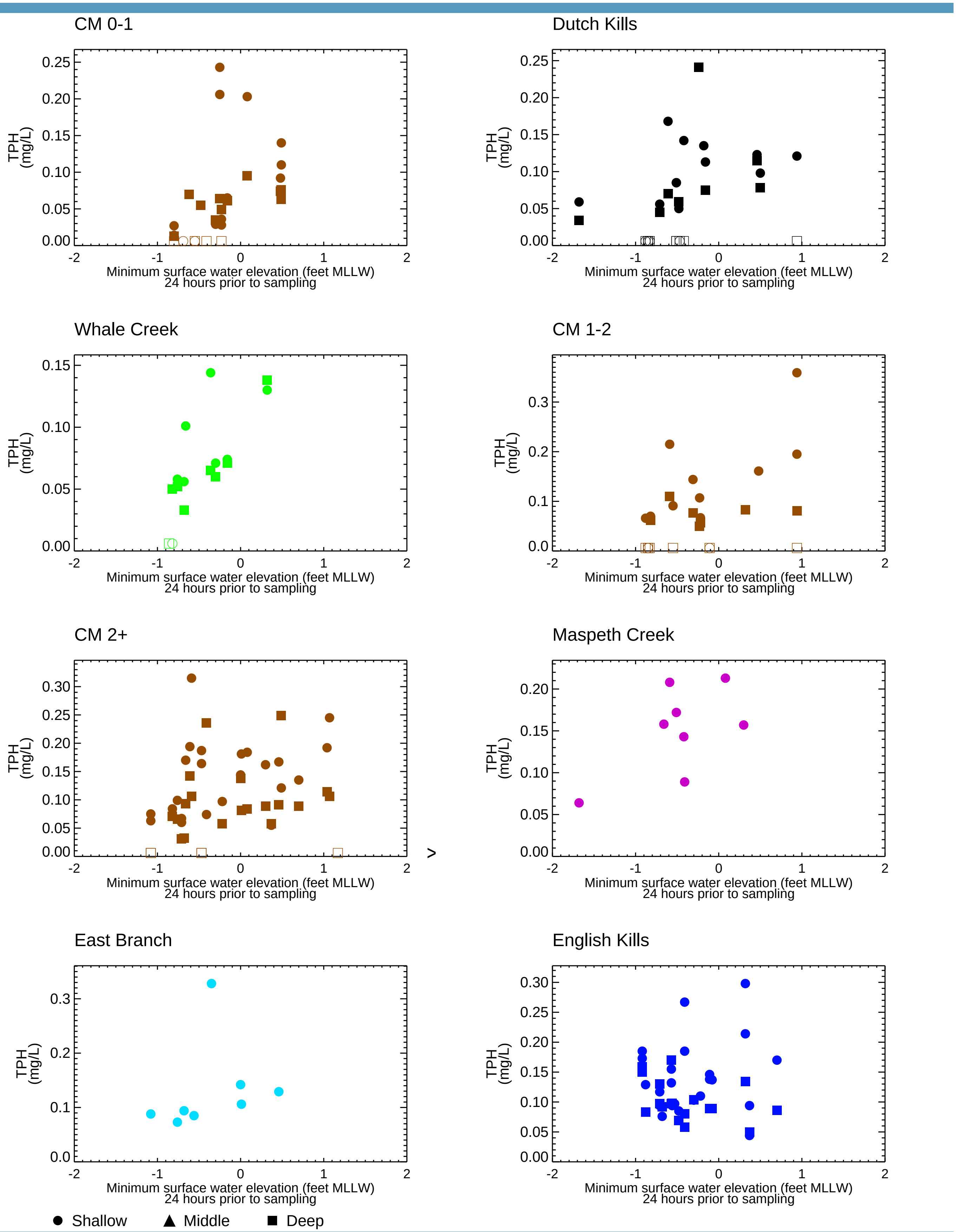


Figure D5-13f

TPH in Surface Water During Dry Weather Sampling versus Minimum Tide Height 24 Hours Prior to Collection - October through May (2012 - 2014)
Gas Ebullition Evaluation
Newtown Creek RI/FS

Notes: Non-detects, if present, set to the MDL and plotted with open symbol. TPH was not analyzed in dry weather samples collected in Phase 2. Phase 1 samples collected in February through May 2012, October 2012 through January 2013. Shallow samples collected within 3 feet of water surface, middle samples from midpoint of water depth, and deep samples collected within 3 feet of sediment surface. MLLW: mean lower low water.

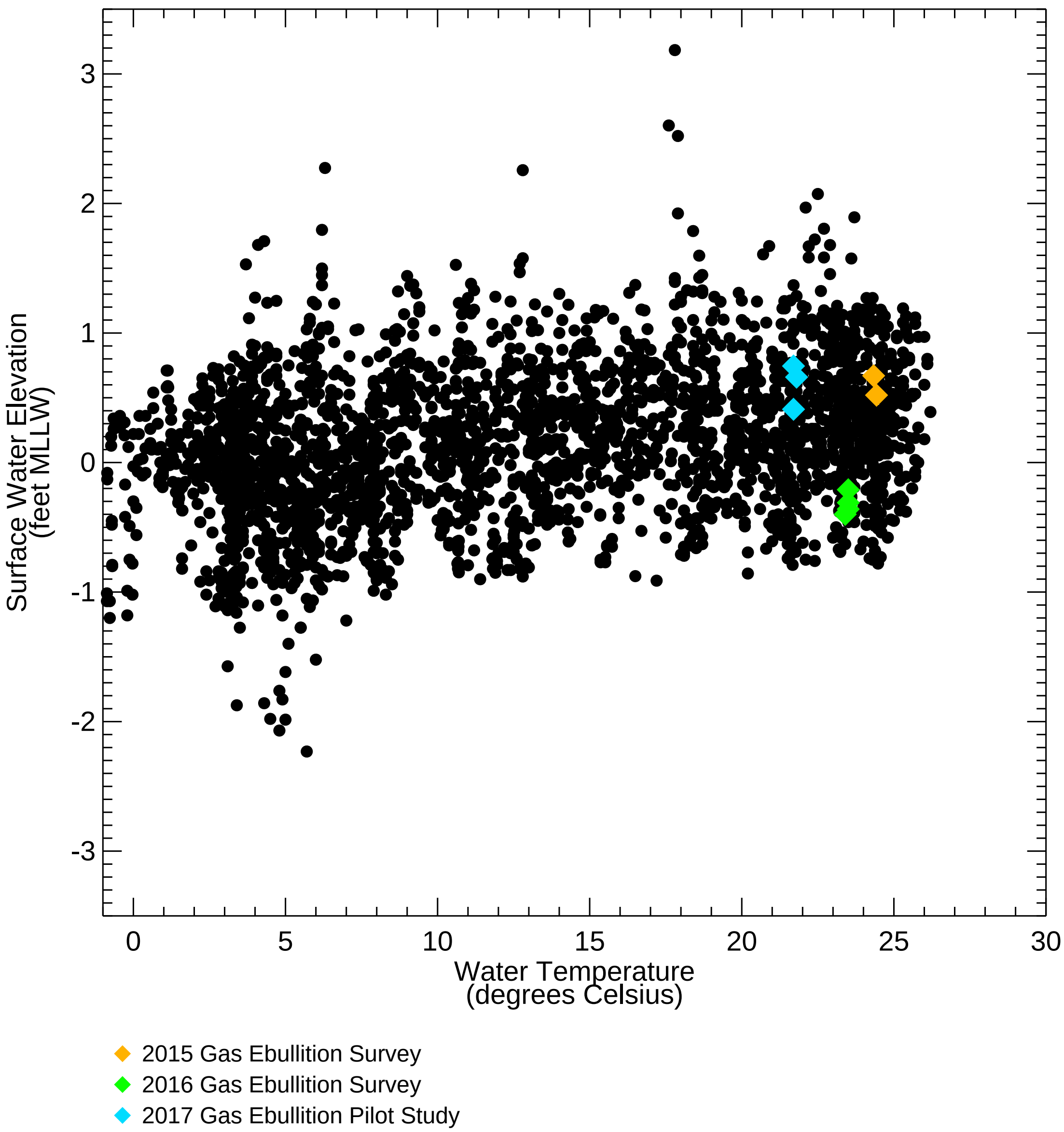


Figure D6-1

Low Tide Surface Water Elevations Compared to Surface Water Temperatures
Gas Ebullition Evaluation
Newtown Creek RI/FS

ANCHOR QEA

Notes: Estimated tidal elevation data, referenced to the mean lower low water (MLLW) tidal datum, obtained from National Oceanic and Atmospheric Administration (NOAA) for Hunters Point, Newtown Creek, NY. Surface water temperatures obtained from NOAA for The Battery, NY.

ATTACHMENT D-1
FULL FLOW PENETRATION TEST SUMMARY AND STANDARD FULL FLOW PENETRATION TEST PLOTS

Full Flow Penetration Test Summary and

Standard Full Flow Penetration Test Plots

ConeTec

CONETEC

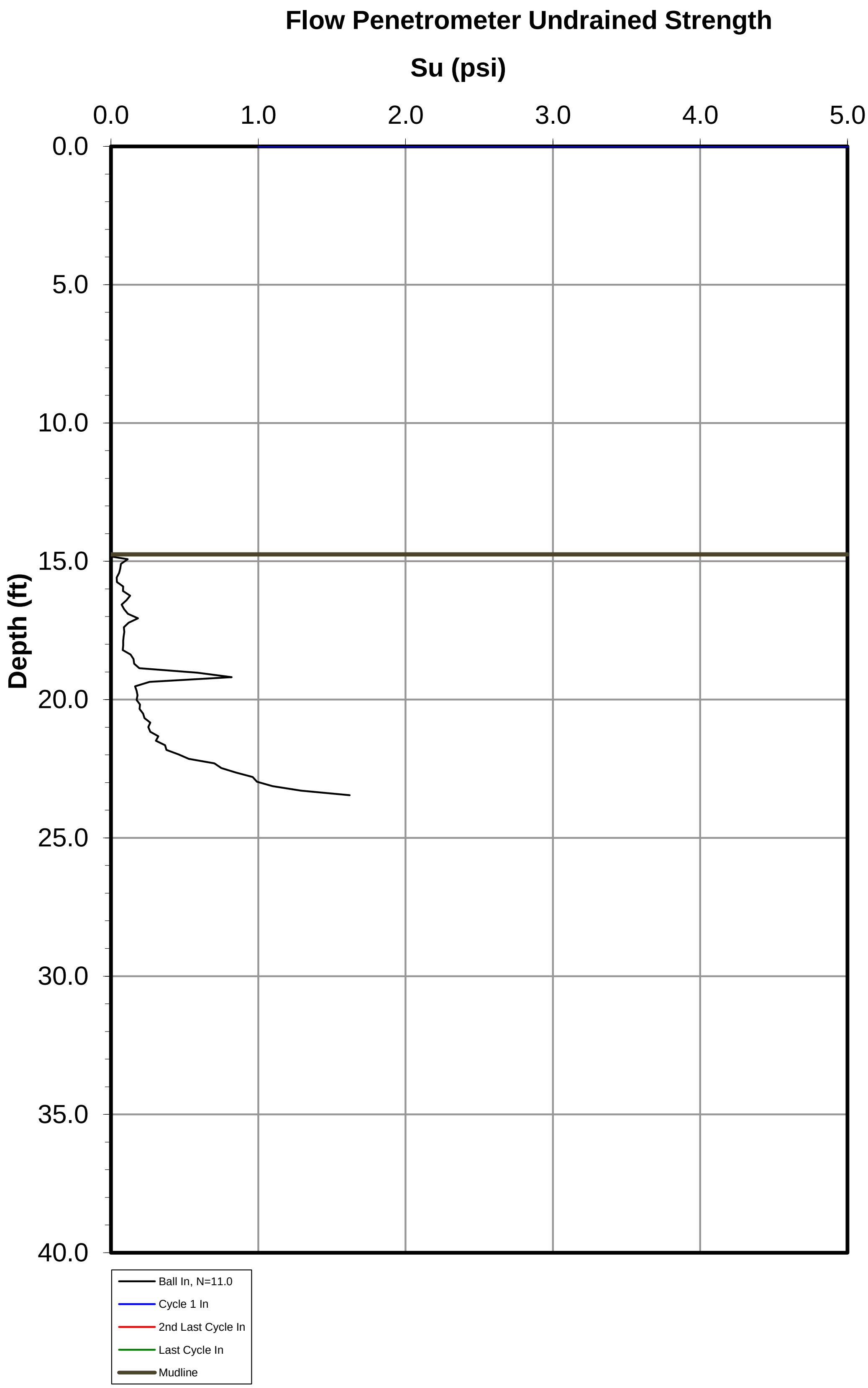
Job No: 17-53155
Client: Anchor QEA
Project: Newtown Creek FS, Brooklyn, NY
Start Date: 08-Nov-2017
End Date: 24-May-2018

FULL FLOW PENETRATION (BALL) TEST SUMMARY

Sounding ID	File Name	Date	Cone	Cone Area (cm^2)	Ball Area (cm^2)	Final Depth (ft)	Northing[1] (m)	Easting (m)
BCPT18-EB057	17-53155_BPEB057	22-May-2018	310:T1000F10U500	10	60	23.46	4507933	590940
BCPT17-EK013IP	17-53155_BPEK013	15-Nov-2017	310:T1000F10U500	10	60	18.70	4507488	590319
BCPT17-EK021IP	17-53155_BPEK021	15-Nov-2017	310:T1000F10U500	10	60	14.44	4507197	590263
BCPT17-EK103IP	17-53155_BPEK103	14-Nov-2017	310:T1000F10U500	10	60	22.47	4507909	590498
BCPT17-EK114IP	17-53155_BPEK114	15-Nov-2017	310:T1000F10U500	10	60	31.33	4507932	590537
BCPT18-MC035	17-53155_BPMC035	21-May-2018	190:T1000F10U500	10	60	25.75	4508664	590834
BCPT18-NC014	17-53155_BPNC014	23-May-2018	310:T1000F10U500	10	60	24.93	4510385	588279
BCPT18-NC014IP	17-53155_BPNC014IP	3-Jan-2018	310:T1000F10U500	10	60	27.56	4510379	588277
BCPT18-NC039	17-53155_BPNC039	22-May-2018	310:T1000F10U500	10	60	21.33	4509747	589428
BCPT17-NC050IP	17-53155_BPNC050	20-Nov-2017	310:T1000F10U500	10	60	25.75	4509326	589728
BCPT17-NC069IP	17-53155_BPNC069	17-Nov-2017	310:T1000F10U500	10	60	35.27	4508613	590632
BCPT17-NC342IP	17-53155_BPNC342	16-Nov-2017	310:T1000F10U500	10	60	29.69	4508270	590767
BCPT17-NC346IP	17-53155_BPNC346	21-Nov-2017	310:T1000F10U500	10	60	24.28	4510329	588540
BCPT17-NC347IP	17-53155_BPNC347	21-Nov-2017	310:T1000F10U500	10	60	12.80	4510132	588877
BCPT18-NC349	17-53155_BPNC349	23-May-2018	310:T1000F10U500	10	60	28.21	4510007	589207
BCPT17-NC352IP	17-53155_BPNC352	20-Nov-2017	310:T1000F10U500	10	60	19.19	4509605	589534
BCPT17-NC360IP	17-53155_BPNC360	20-Nov-2017	310:T1000F10U500	10	60	34.44	4509070	590464
BCPT17-NC363IP	17-53155_BPNC363	17-Nov-2017	310:T1000F10U500	10	60	36.74	4508723	590748
BCPT17-NC371IP	17-53155_BPNC371	17-Nov-2017	310:T1000F10U500	10	60	17.06	4508352	590832
BCPT18-WC003	17-53155_BPWC003	24-May-2018	310:T1000F10U500	10	60	21.16	4509922	588919

1. Coordinates are WGS 84 / UTM Zone 18 and were collected using MR350 GlobalSat GPS Receiver.

Project: 17-53155
Client: Anchor QEA
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT18-EB057
Sounding Date: 5/22/2018



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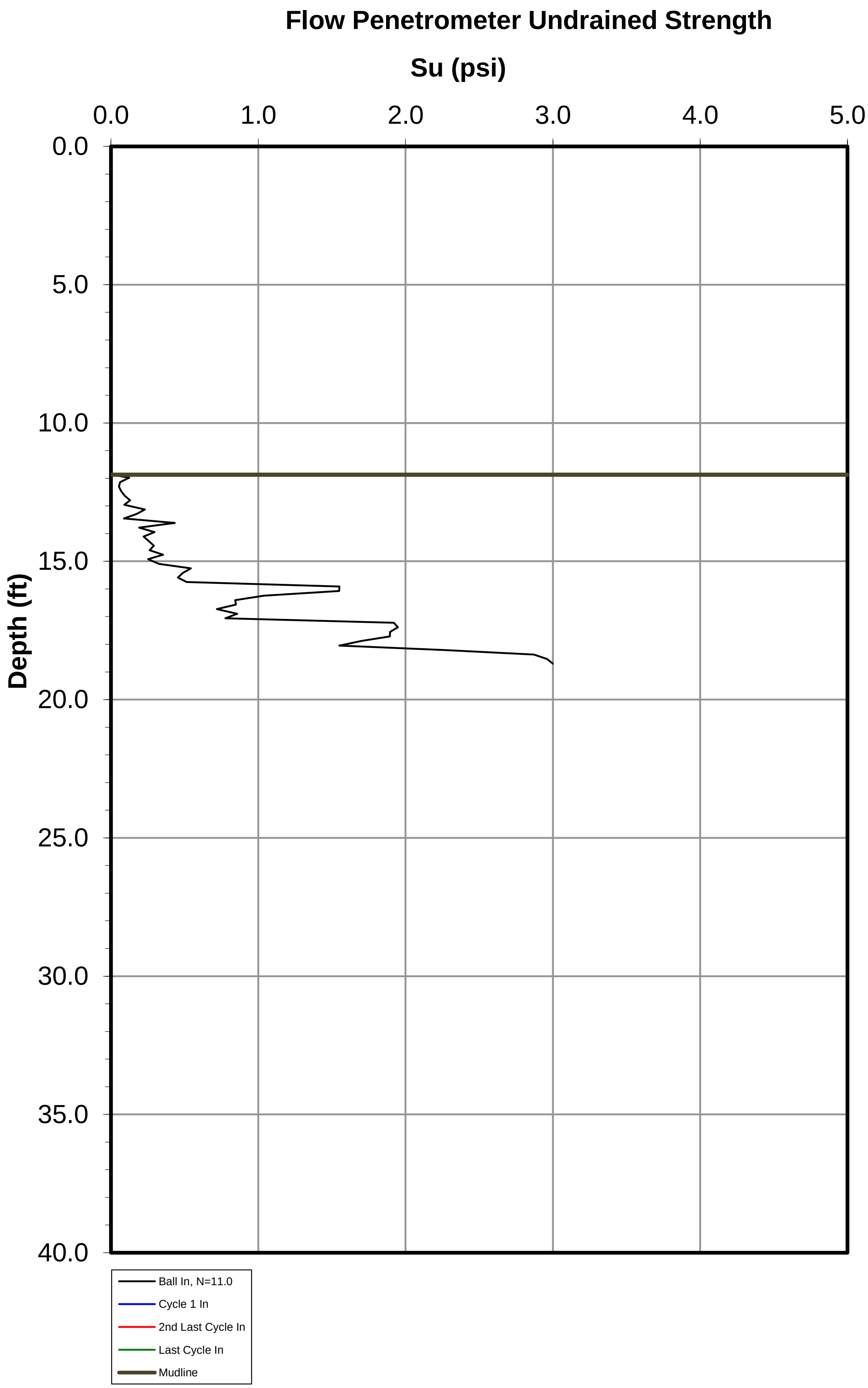
Client: Anchor QEA
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT17-EK013IP
Sounding Date: 11/15/2017



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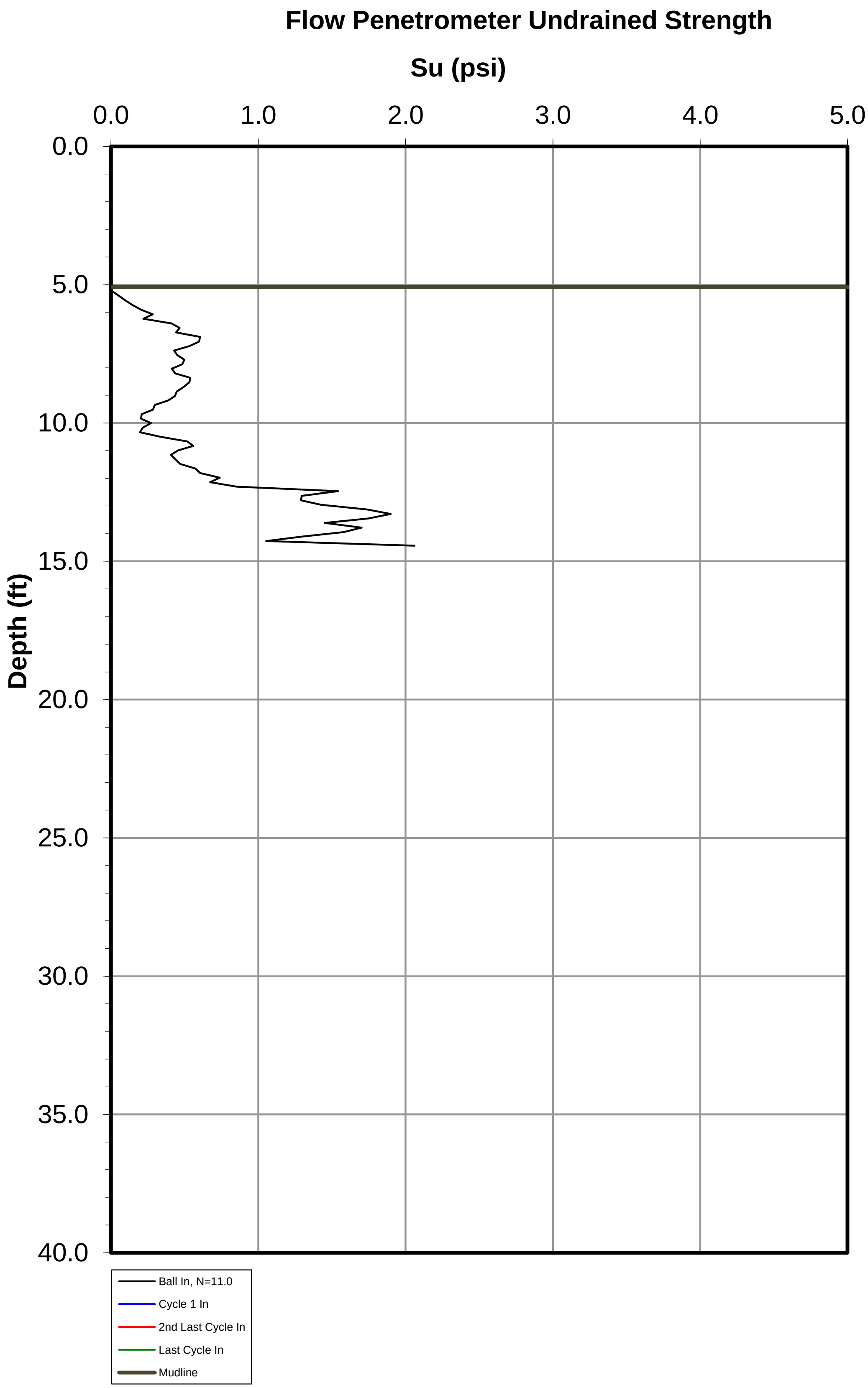
Sounding Date: 11/15/2017



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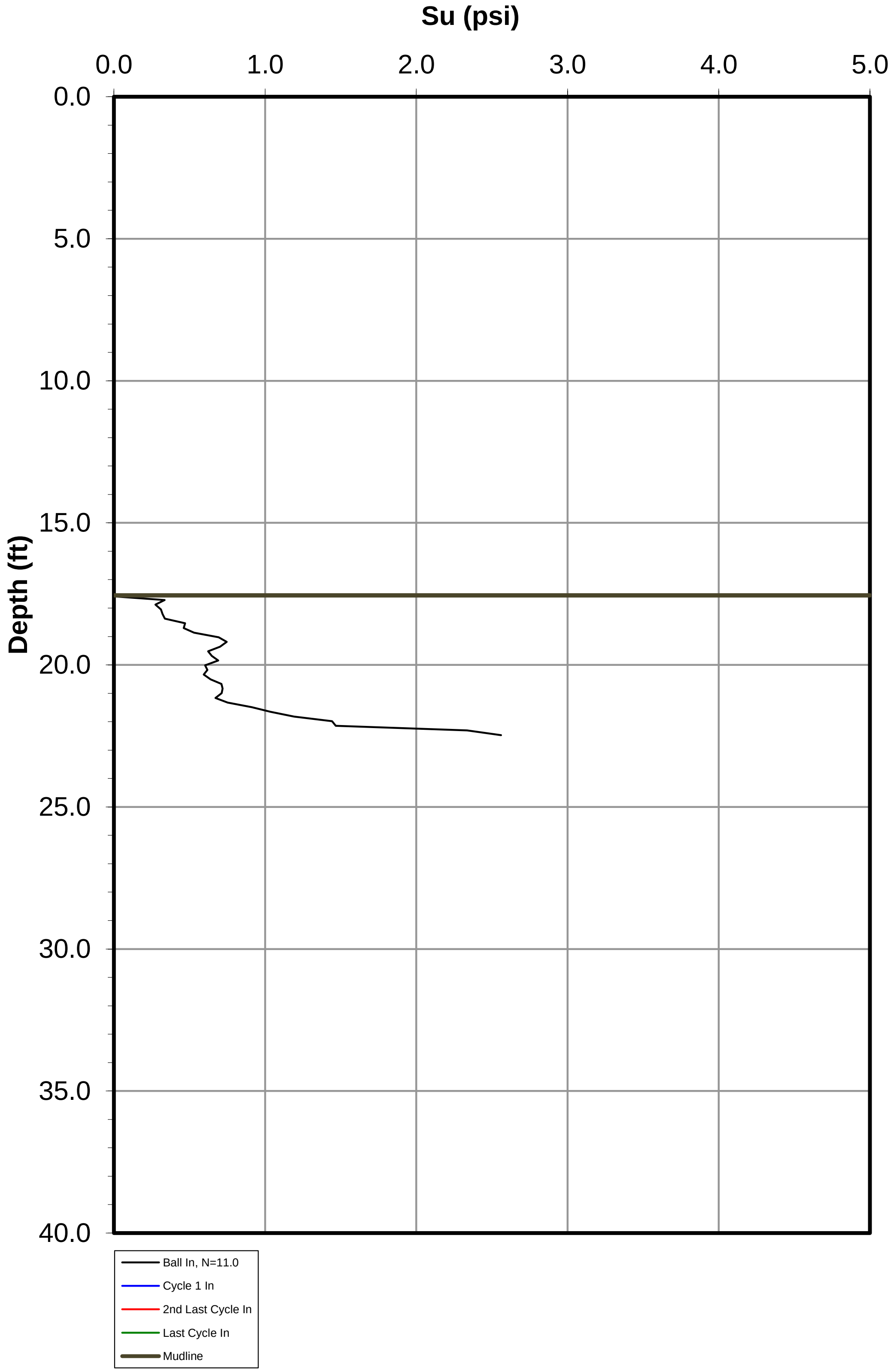
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT17-EK103IP
Sounding Date: 11/14/2017

Flow Penetrometer Undrained Strength



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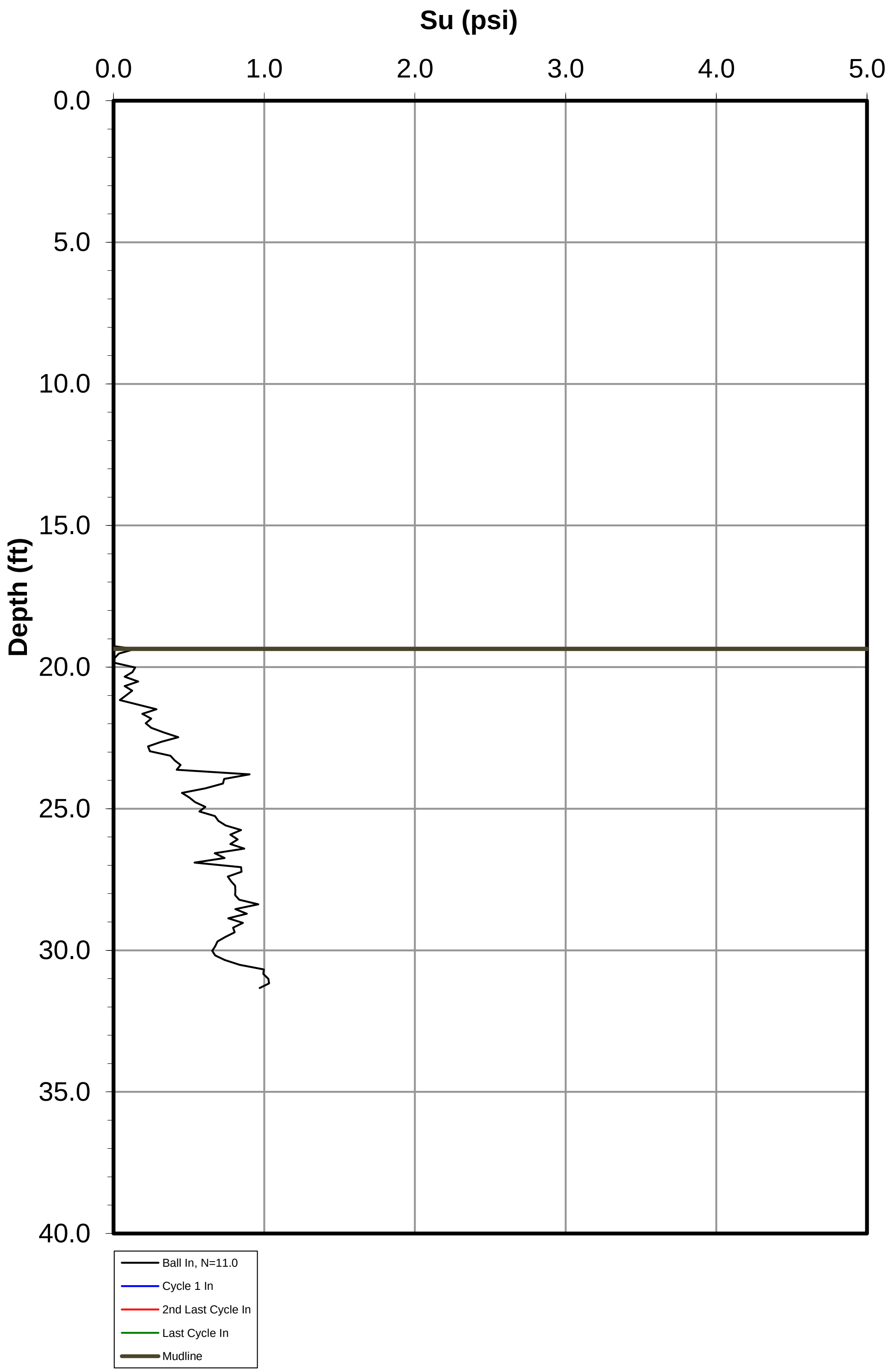
Sounding: BCPT17-EK114IP
Sounding Date: 11/14/2017

Flow Penetrometer Undrained Strength



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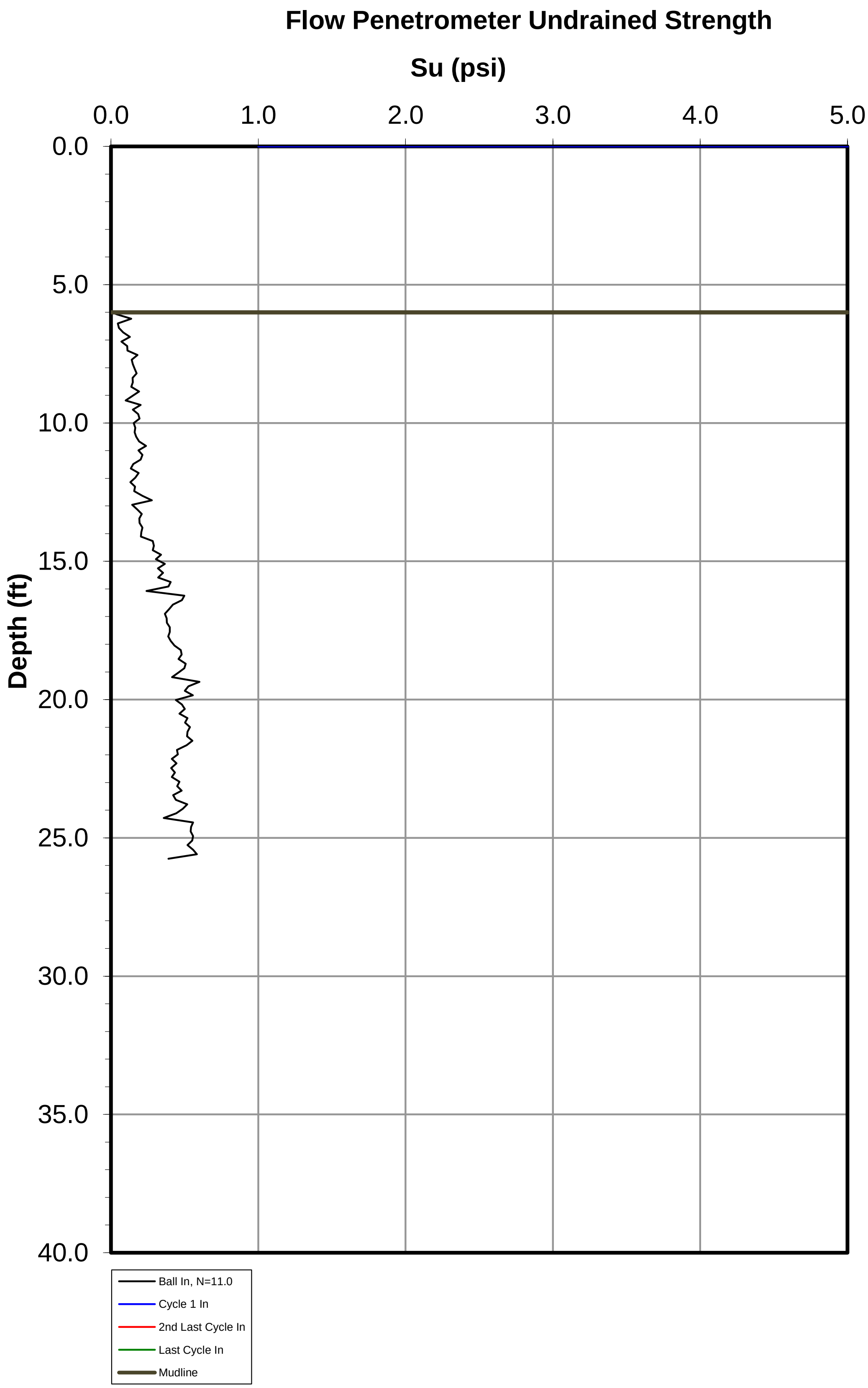
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT18-MC035
Sounding Date: 5/21/2018



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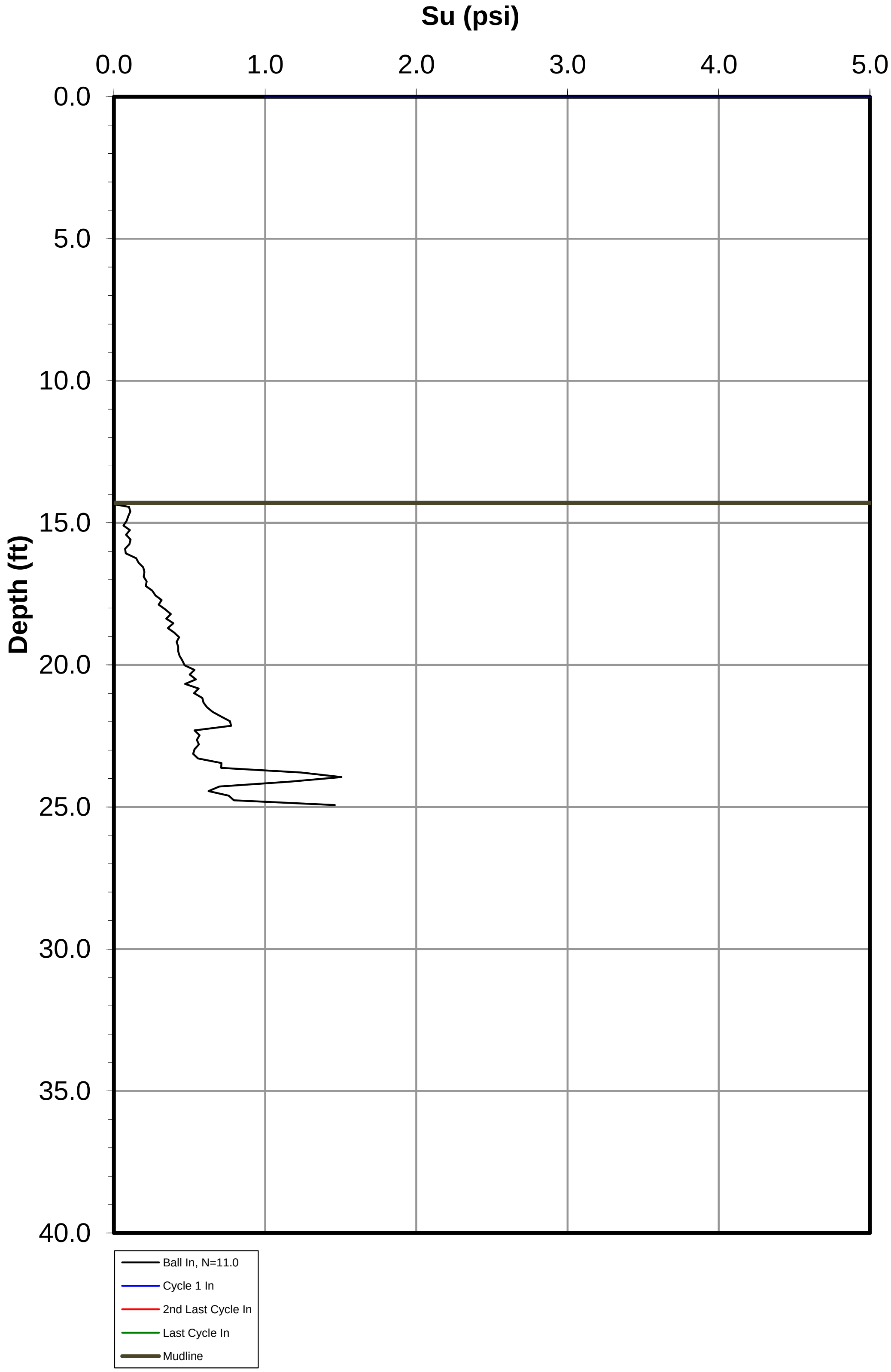
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT18-NC014
Sounding Date: 5/23/2018

Flow Penetrometer Undrained Strength



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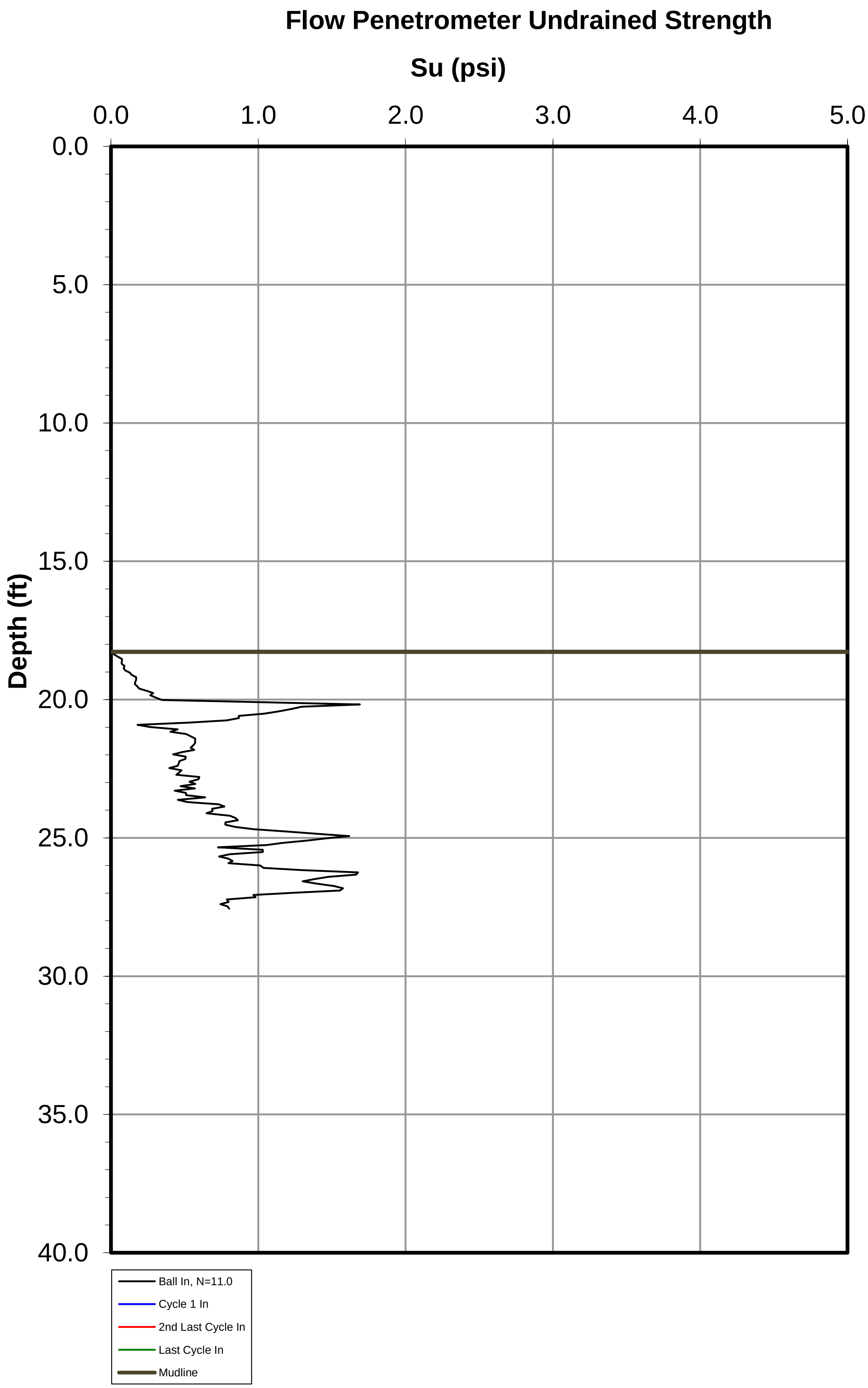
Client: Anchor QEA
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT18-NC014IP
Sounding Date: 1/3/2018



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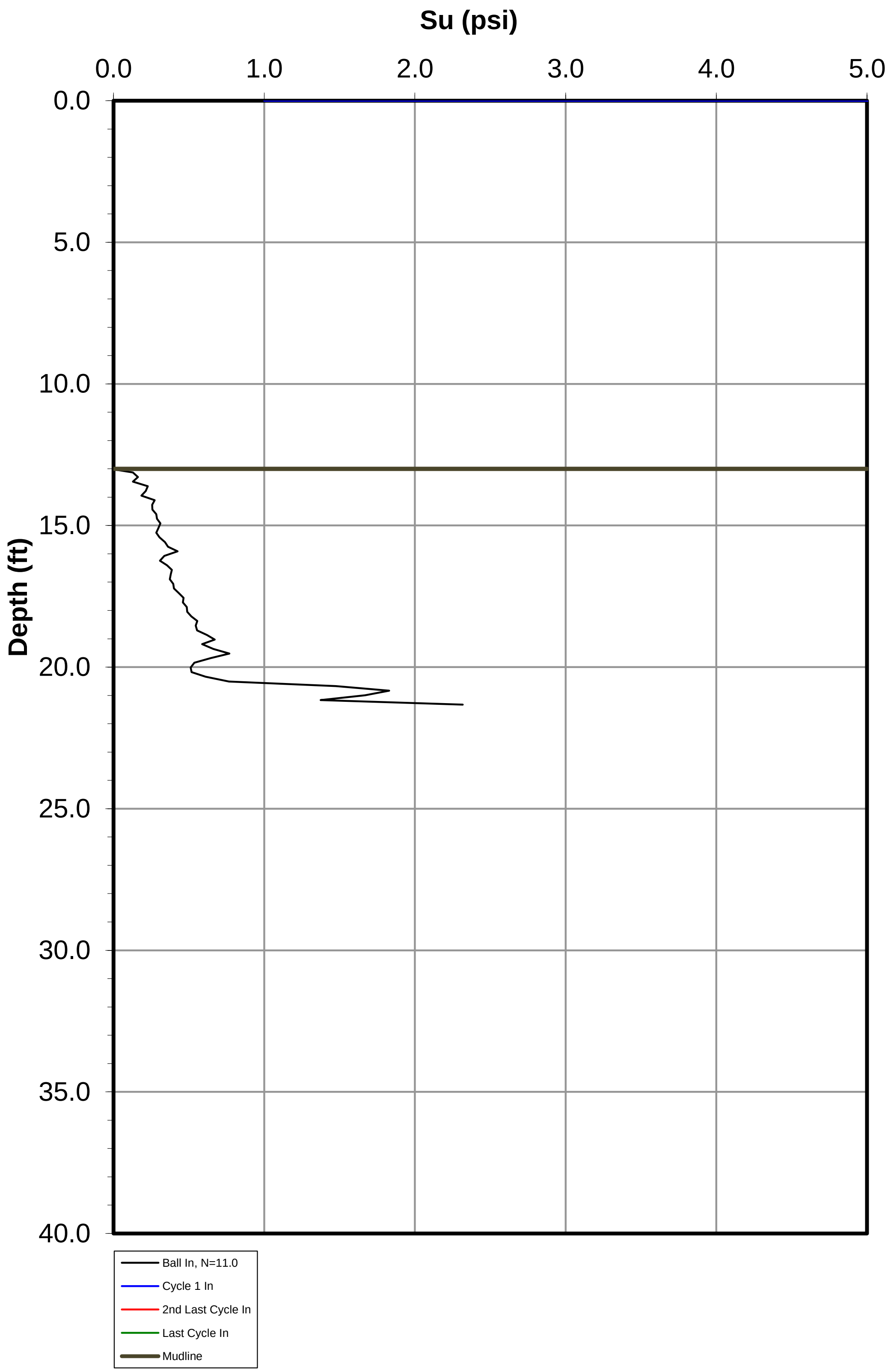
Client: Anchor QEA
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT18-NC039
Sounding Date: 5/22/2018

Flow Penetrometer Undrained Strength



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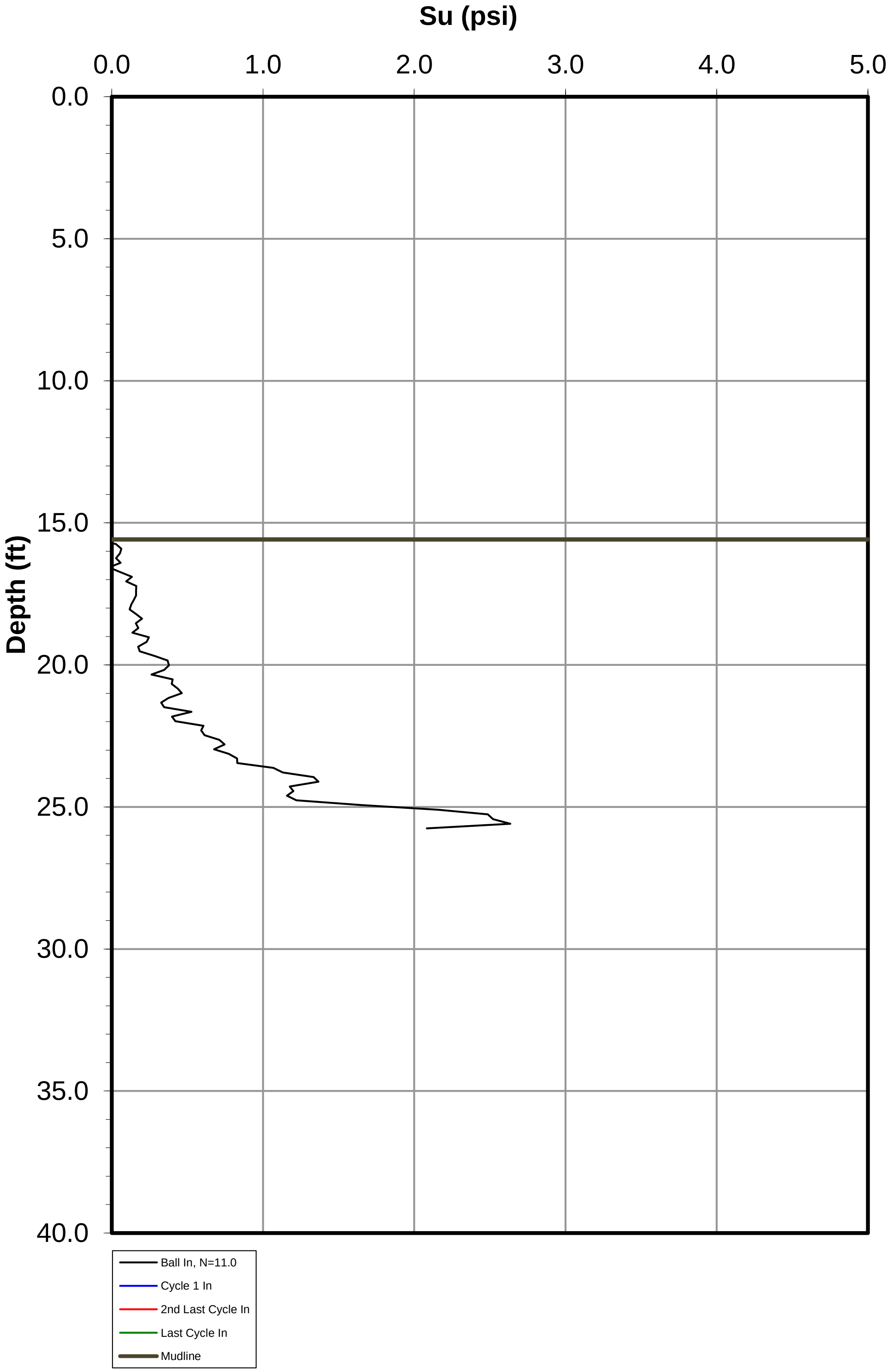
Client: Anchor QEA
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT17-NC050IP
Sounding Date: 11/20/2017

Flow Penetrometer Undrained Strength



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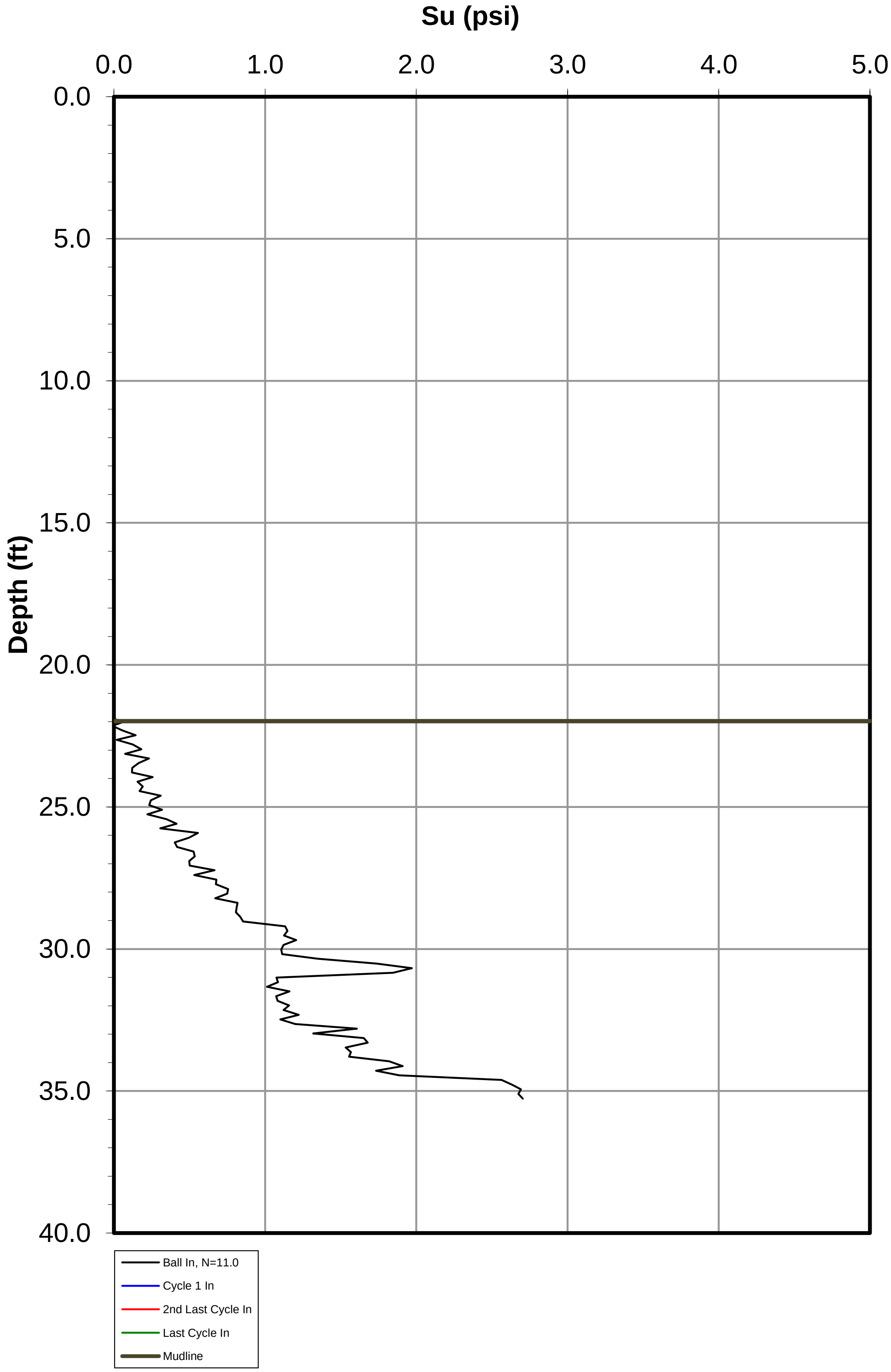
Sounding: BCPT17-NC069IP
Sounding Date: 11/16/2017

Flow Penetrometer Undrained Strength



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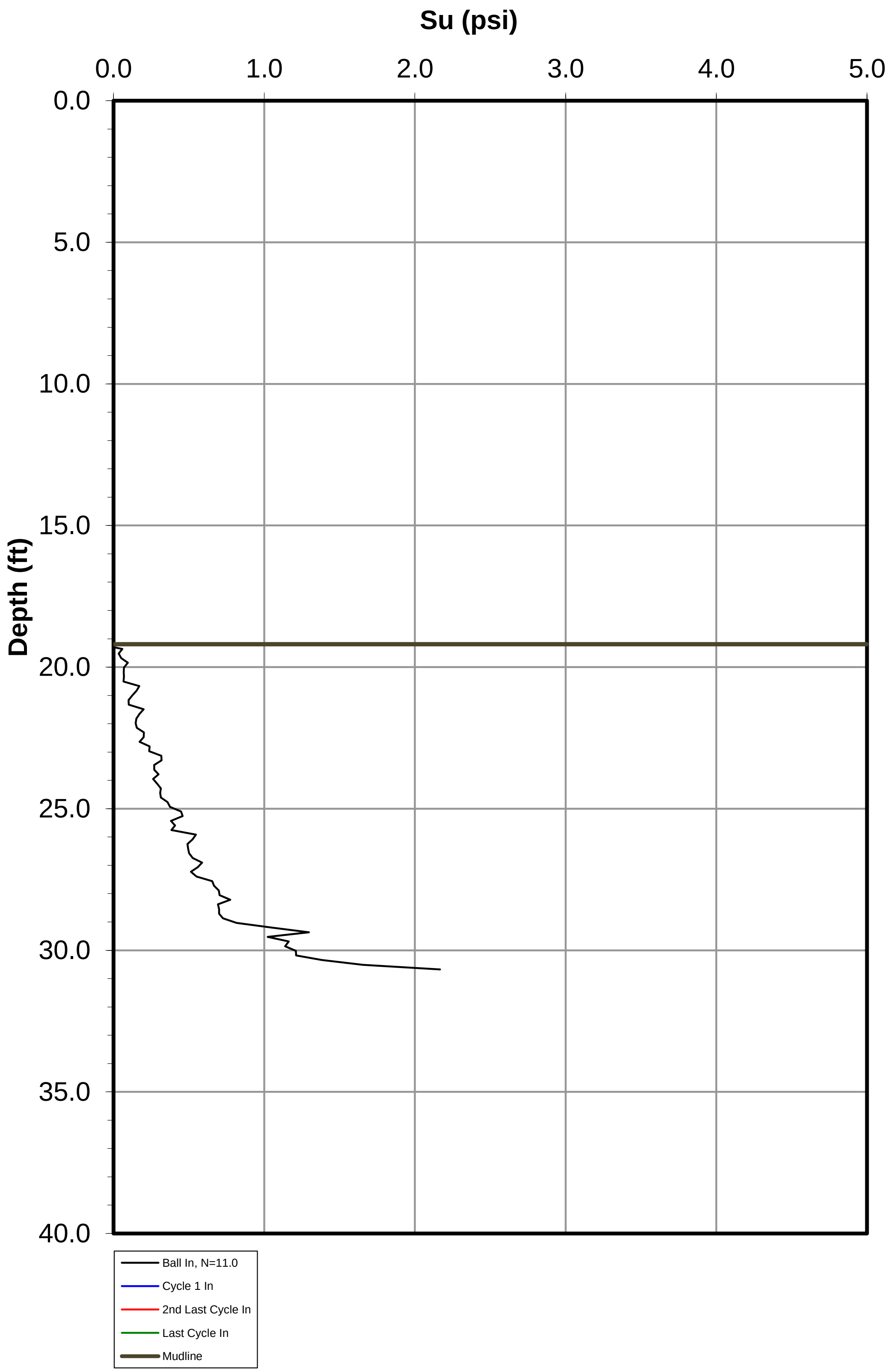
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT17-NC342IP
Sounding Date: 11/16/2017

Flow Penetrometer Undrained Strength



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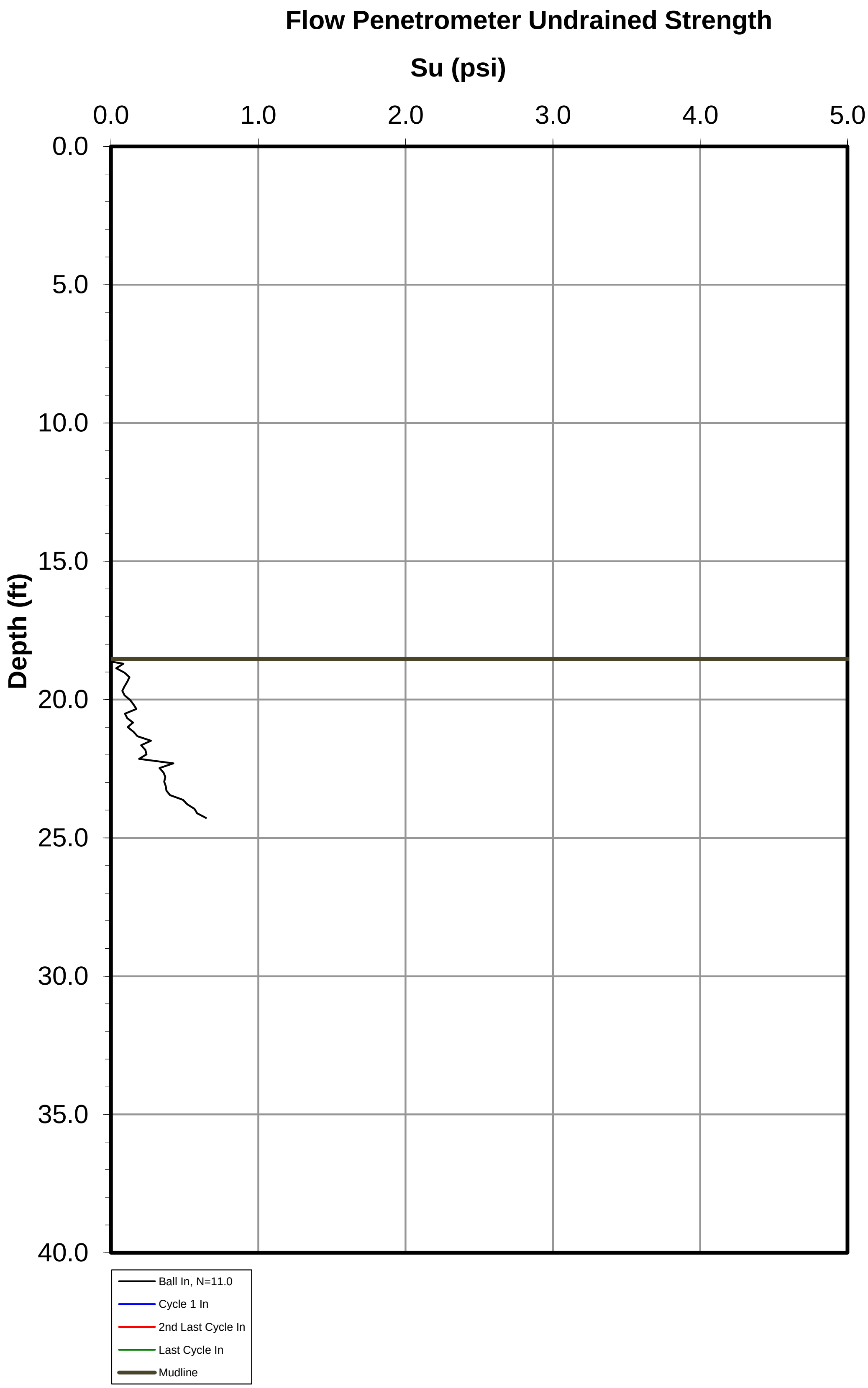

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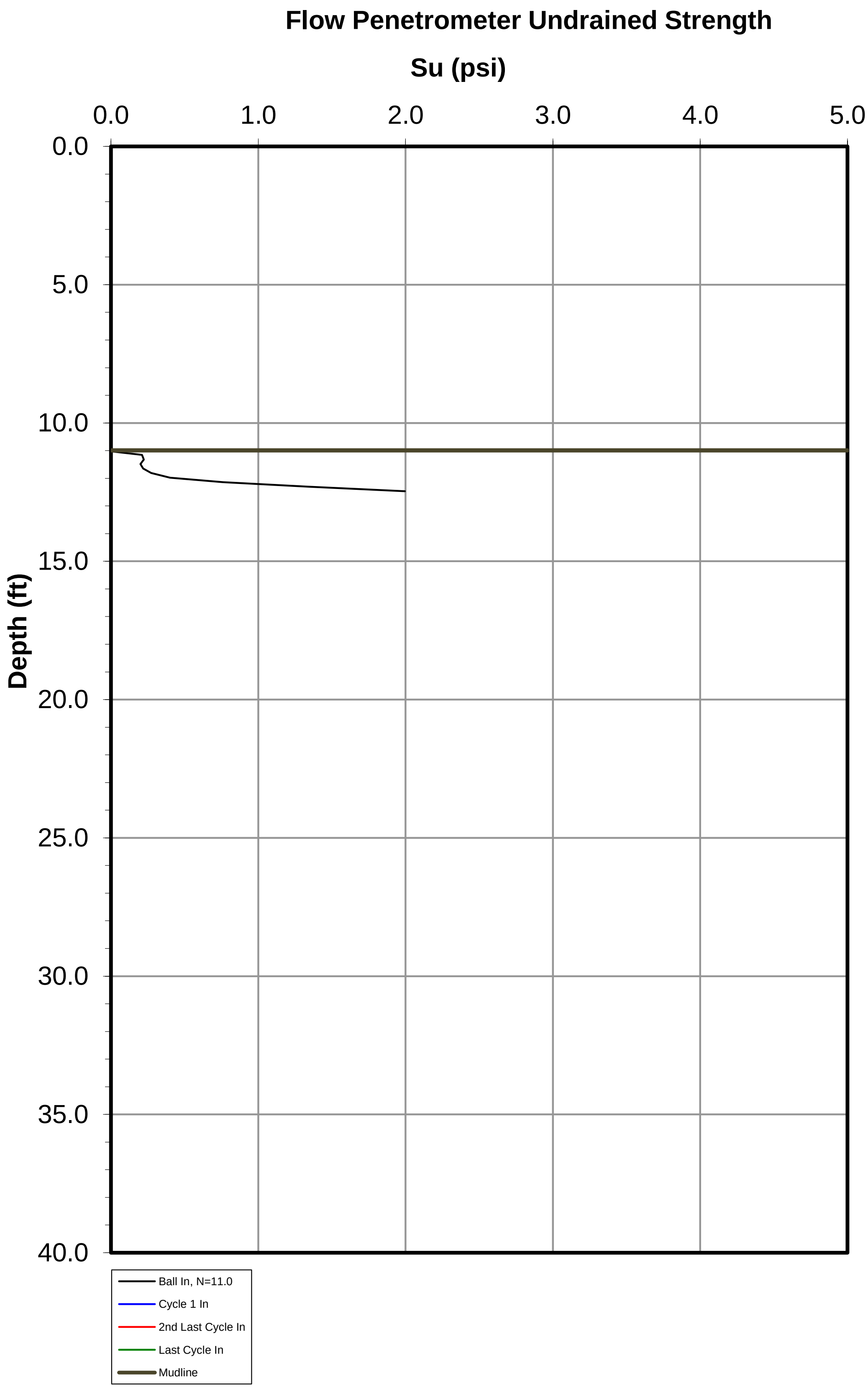
Sounding Date: 11/21/2017



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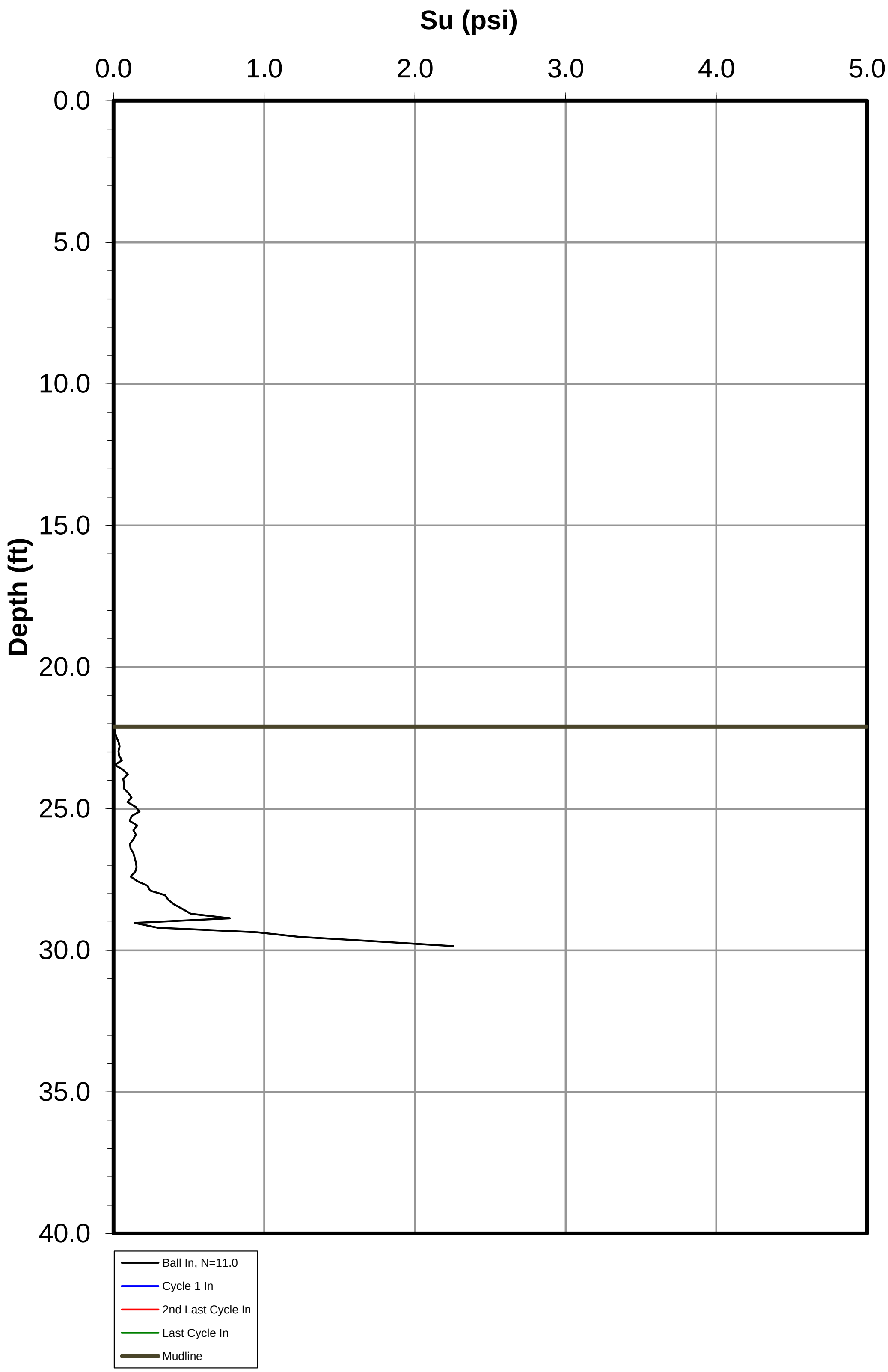
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT18-NC349
Sounding Date: 5/23/2018

Flow Penetrometer Undrained Strength



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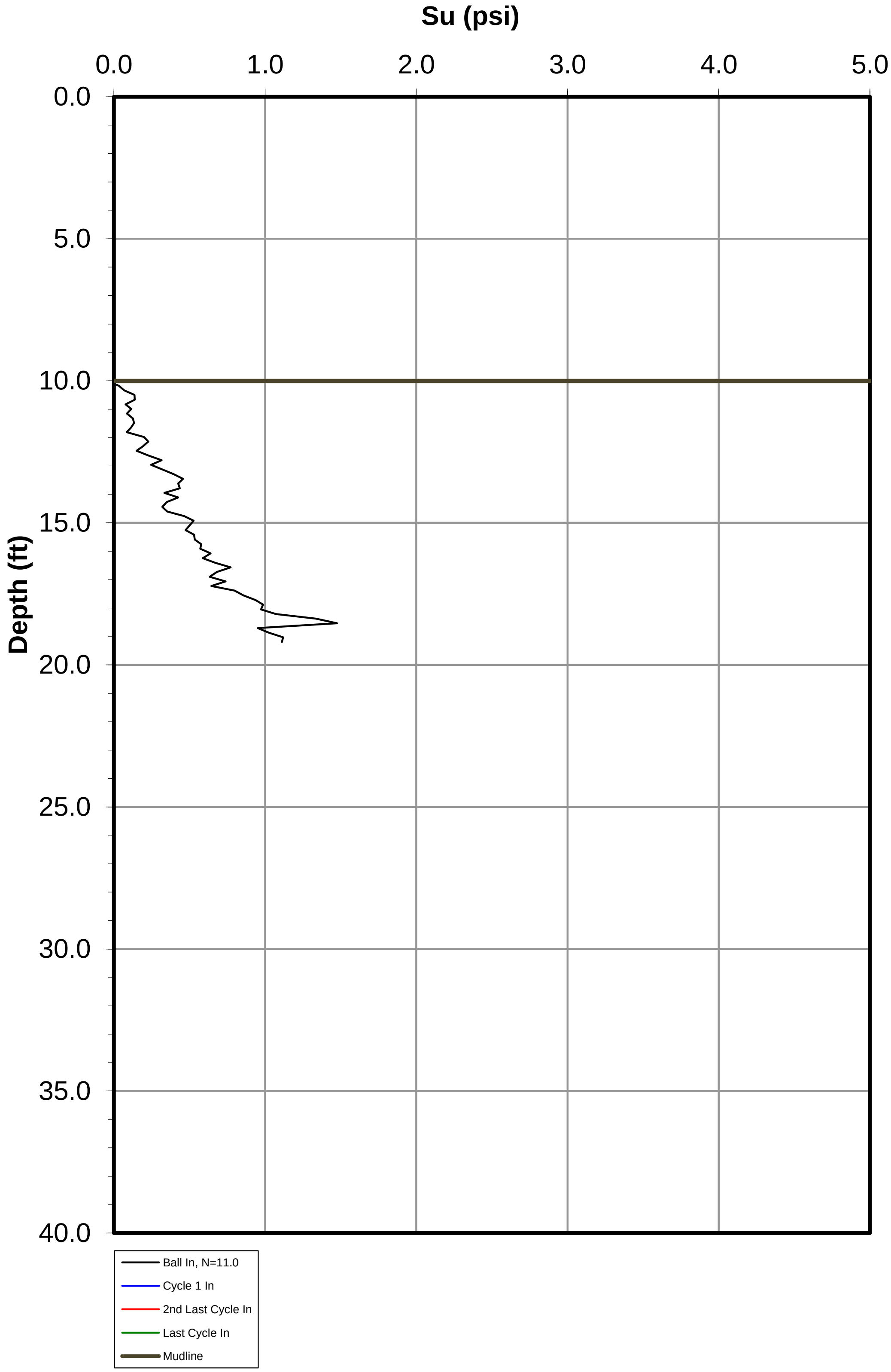
Client: Anchor QEA
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT17-NC352IP
Sounding Date: 11/20/2017

Flow Penetrometer Undrained Strength



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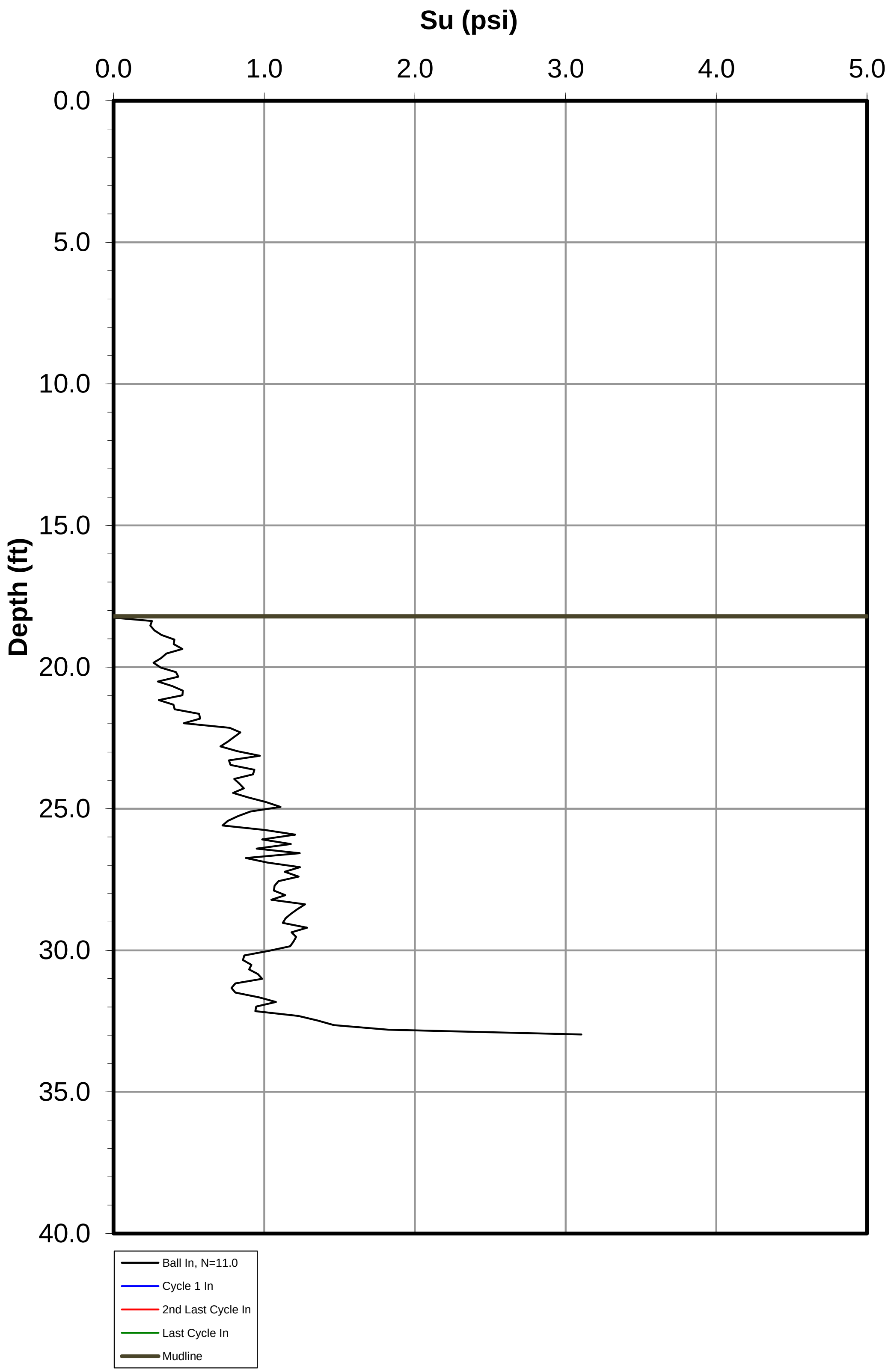
Client: Anchor QEA
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT17-NC360IP
Sounding Date: 11/20/2017

Flow Penetrometer Undrained Strength



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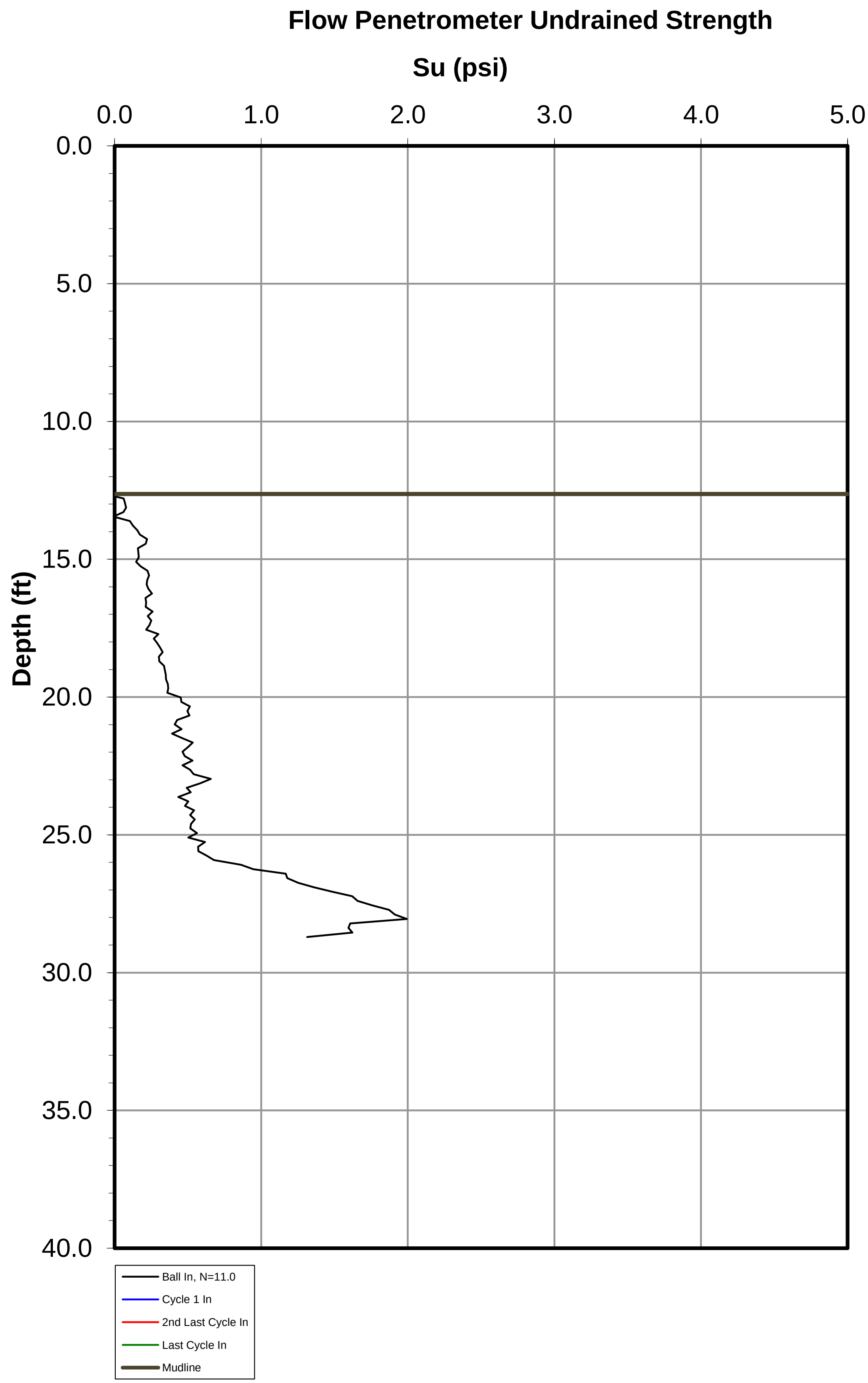

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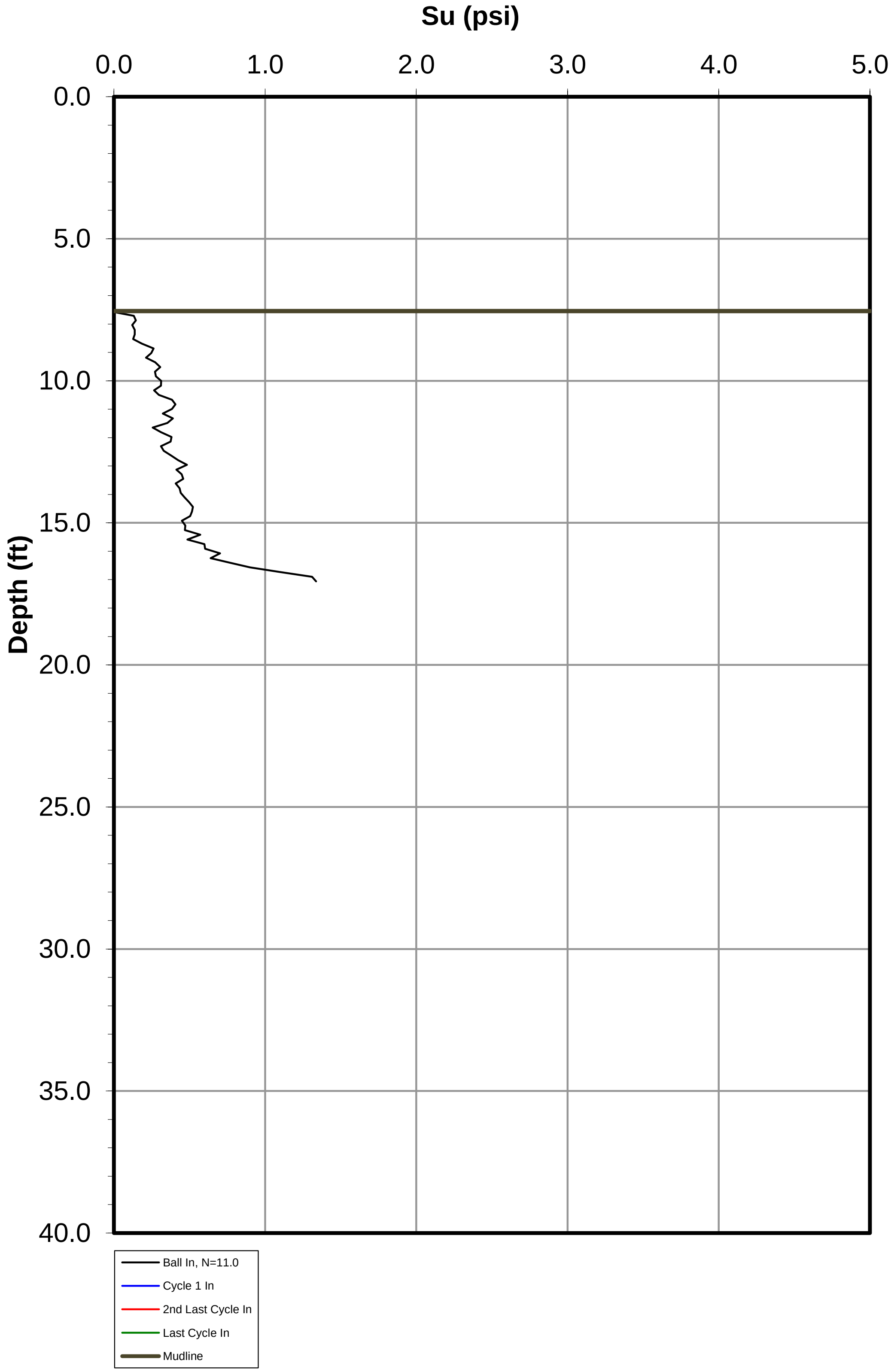
Project: Newtown Creek FS, Brooklyn, NY
Sounding: BCPT17-NC371IP
Sounding Date: 11/17/2017

Flow Penetrometer Undrained Strength



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